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Elementary Cognitive Tasks of Executive Functioning: A Concurrent Validity Study

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ELEMENTARY COGNITIVE TASKS OF EXECUTIVE FUNCTIONING: A CONCURRENT VALIDITY STUDY

by

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ABSTRACT

ELEMENTARY COGNITIVE TASKS OF EXECUTIVE FUNCTIONING: A CONCURRENT VALIDITY STUDY

by

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In this study, we examined the concurrent validity of four computerized elementary cognitive tasks (ECTs) by comparing them with Delis–Kaplan Executive Function System's (D-KEFS) scores shown to load on the three-factor model of executive functions (EFs). A sample of 175 college students were administered two ECTs purportedly measuring perceptual-motor skills (simple and choice reaction time [RT] tasks) and two ECTs purportedly measuring executive control (1- & 2-bit internal-rule [IR] tasks), as well as the D-KEFS Sorting Test, Color-Word Test, and Verbal Fluency Test to assess Shifting, Inhibition, and Updating, respectively. Specific D-KEFS scores underwent principal component analysis, yielding a three-factor solution consistent with the factor structure of the D-KEFS. Correlations and hierarchical regression analyses were performed to identify both the relationships and the contributions of the D-KEFS factors to each ECT. Moderate correlations were seen between the Inhibition factor and the four ECTs, whereas the Updating and Shifting factors had low correlations with the direct-response tasks and the 2-bit IR task, respectively. Results also showed that after controlling for Updating, Inhibition was the most important predictor of task performance across the ECTs. As expected, Updating predicted both simple and choice RT task performances and Shifting predicted internal-rule task performances; however, Shifting unexpectedly predicted performance on the choice RT task. Overall, previous findings using the ECTs were replicated, but did not strongly support D-KEFS factor differentiation among the ECTs, although typical correlations between speed and power tasks were evident, providing evidence of the concurrent validity of the ECTs. Findings were in line with the unity and diversity conceptualization of EFs. Clinical and theoretical implications as well as study limitations are discussed along with suggestions for future directions using the ECTs.

Keywords: Elementary cognitive tasks, Executive functions, Concurrent validity

A

mis padres,

cuyo apoyo continuo

para alcanzar

mis metas personales y profesionales

ha sido indispensable e invaluable,

y con quienes

estaré en deuda para siempre.

To

my parents,

whose continuous support

for me to achieve

my personal and professional goals

have been indispensable and invaluable,

and with whom

I will be forever indebted.

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Introduction

Executive functions (EFs) are an umbrella term covering a number of abilities (Allport, 1993; Baddeley, 1986; Parkin, 1998). EFs also present an important area for research and clinical consideration as executive deficits have been implicated in a variety of disorders, such as attention deficit hyperactivity disorder (ADHD), anxiety, and depression (see Alexander & Stuss, 1999; Miyake, Emerson, & Friedman, 1999; Darvishzadeh, Aguilar-Vafaie, & Moradi, 2012; Nigg et al., 2005; Tandon, Singh, Sinha, & Trivedi, 2002; Tucker & Derryberry, 1992). The most commonly referenced EFs are mental set shifting (referred also as "switching," "task switching," "attention switching," or "Shifting"), information updating and monitoring ("Updating"), and inhibition of responses ("Inhibition") (Logan, 1985; Miyake et al., 2000). According to Miyake et al.'s (2000) well-established factor model of EFs, which is based on relatively simple EF tasks, executive control consists of these three main components (see also Collette et al., 2005; Miyake & Friedman, 2012). Although there has been an increased interest in developing relatively simple experimental tasks to tap basic EFs, work today continues with the underlying, but not well researched, assumption that EFs are qualitatively different from other cognitive abilities (Salthouse, Atkinson, & Berish, 2003), such as perceptual-motor abilities. If executive processes were qualitatively distinct from perceptual-motor processes, then different performance patterns would be expected between executive control and perceptual-motor tasks.

One method of attempting to differentiate EFs from perceptual-motor abilities is to design elementary cognitive tasks (ECTs) defined according to the rubric of mental set and information theory. It is plausible that the difficulty in selectively assessing EFs, apart from "lower-order" cognitive processes (e.g., perceptual-motor skills) on which they depend, turns on translating executive control into an appropriate measurement operationalization. In other words, being able to operationalize executive control may facilitate measurement of EFs apart from other non-EF cognitive functions. Therefore, four ECTs were created; two tasks purportedly measuring perceptual-motor skills (simple and choice reaction time [RT] tasks) and two tasks purportedly measuring executive control (1- and 2-bit internal-rule [IR] tasks). The four ECTs offer several advantages compared to complex EF tasks (e.g., Wisconsin Card Sorting Test [WCST]), such as having seemingly fewer cognitive processes, graded task difficulty defined mathematically, high construct penetrance, a flexible computerized platform, ratio-level measurement, and being able to differentiate inter-individual differences.

Since preliminary studies using the ECTs have suggested that the internal-rule tasks are seemingly qualitatively different from the direct-response tasks and provided proof-of-concept for the executive nature of the internal-rule tasks, in the present study we examined the concurrent validity of computerized ECTs. Having designed the ECTs in an attempt to differentiate executive control processes from perceptual-motor skills, they were compared with specific Delis–Kaplan Executive Function System's (D-KEFS; Delis, Kaplan, & Kramer, 2001a) scores shown to load on Miyake et al.'s (2000; as cited in Lazman & Markon, 2010) three-factor model of EFs.

The three-factor model of executive functions

Miyake et al.'s (2000) three-factor model is composed of three relatively basic EFs: Updating, Inhibition, and Shifting. Updating requires monitoring and evaluating new information in working memory (WM). Inhibition requires deliberately controlling responses (i.e., automatic or effortful responses) where necessary (Logan, 1994; Miyake et al., 2000) and has been conceptually broken down into multiple inhibitory functions (e.g., inhibiting a prepotent and automatic response or inhibiting an already planned action; Friedman & Miyake, 2004). Finally, Shifting requires switching from an irrelevant set to a relevant set according to the task (Miyake et al., 2000; Monsell, 2003). The three-factor model of EFs has been supported by several factor analytical studies using cognitively normal college and adult populations (see Fisk & Sharp, 2004; Friedman & Miyake, 2004; Friedman et al., 2006; Hull, Martin, Beier, Lane, & Hamilton, 2008; Miyake & Friedman, 2012; Miyake et al., 2000). Such studies have shown that executive control tasks differentially contribute to Shifting, Updating, and Inhibition (e.g., WCST performance is related most strongly to Shifting), and that these basic EFs are both moderately correlated with one another and clearly separable, also known as the "unity and diversity" conceptualization of EFs (Miyake & Friedman, 2012; Miyake et al., 2000). Therefore, the three-factor model provides a useful framework for studies investigating the contribution of basic EFs to executive control tasks as well as the factor structure of executive control tasks as described next.

Given the support in the literature across a wide array of experimental tasks for a three-factor model of EFs, Latzman and Markon (2010) examined the factor structure and the age-related factorial invariance of the most commonly used clinical battery for the assessment of EFs, the D-KEFS (Delis et al., 2001a). This study first used total achievement scores from the D-KEFS technical manual (ages 8-89; Delis, Kaplan, & Kramer, 2001b), as they reflect both global subtest performance and traditional measures of EFs overall, and then replicated their findings in an independent sample of early adolescents. Results revealed that a three-factor model best fit the data across groups and samples, although moderate interfactor correlations were also identified along with both invariant and variant measurement properties across age groups. For example, estimated interfactor correlations for 20 to 49-year-olds, the age group specifically relevant for the current study, were as follows: Shifting and Updating (r = .26), Shifting and Inhibition (r = .38), and Updating and Inhibition (r = .45). These results indicated the presence of a higher order EF (i.e., "common EF" factor composed of Inhibition) that is also separable at the lower order level (i.e., Updating and Shifting factors). These D-KEFS results are consistent with previous findings investigating the three-factor model, which suggest that EFs are both unitary and diverse (Miyake & Friedman, 2012; Miyake et al., 2000). Specifically, the three factors were labeled Monitoring (i.e., Updating), Inhibition, and Conceptual Flexibility (i.e., Shifting), and were anchored by specific D-KFES scores from the Verbal Fluency Test, the Color-Word Test and the Sorting Test, respectively. Such scores heavily loaded (> .50) onto the three factors for each age group when using data from the D-KEFS technical manual.

Of note, even though the Verbal Fluency Test was not originally intended to assess WM, its switching score was shown to create prominent WM loads (Rende, Ramsberger, & Miyake, 2002; Troyer, Moscovitch, & Winocur, 1997) and to be associated with the lateral prefrontal cortex (Hirshorn & Thompson-Schill, 2006; Smith & Jonides, 1999), suggesting that such skills are closely related to WM. Moreover, WM is not only a system with both storage and processing components associated with posterior (perceptual) and frontal (executive) brain areas, respectively (Baddeley & Hitch, 1974; D'Esposito et al., 1995), but has also been proposed to be fundamental for executive control to operate based on many theories of EFs (e.g., Baddeley, 1986; Goldman-Rakic, 1995). More recent work on Baddeley's (2000) model of WM has emphasized the intimate connection between the storage and processing components via an intermediate component known as the "episodic buffer." This buffer allows integration across the perceptual slave systems in the service of coordinating perceptual and executive processes. Such integration has been postulated to occur in largely posterior brain areas associated with the dynamic interplay between the dorsal and ventral attention networks (Vossel et al., 2014), which may presumably allow individuals to form, update, and hold a mental set in mind when performing a task.

Overall, results regarding the structure of the D-KEFS in two independent samples parallel findings by Miyake et al.'s (2000; as cited by Latzman & Markon, 2010) three-factor model, showing that EFs are separable but moderately correlated (i.e., EFs are "unitary and diverse"), and are comprised of dissociable but linked frontally mediated functions (Lezak, 2012) that may be measured by D-KEFS subtests. Particularly relevant for the current concurrent validity study is the fact that the aforementioned D-KEFS achievement scores could provide a way to identify what basic EFs might be associated with each ECT's performance. In other words, using the D-KEFS factor structure as a proxy for the three-factor model of EFs could permit the examination of the relationship between basic EFs and the ECTs. A description of the purported perceptual-motor (direct-response) and executive (internal-rule) ECTs is provided next.

Computerized Elementary Cognitive Tasks

One way to adapt ECTs into putative tasks of executive control is to start with traditional simple and choice RT tasks. Such RT tasks are based presumptively upon automatic, perceptual-motor responses that presumably require relatively little executive control (Jensen, 2006), given that all conscious, volitional responses may require at least an organizing mental set (Osmon, 1999). For example, in the case of a direct, perceptual-motor choice RT task (e.g., respond to a left stimulus with a left button press or to a right stimulus with a right button press), the examinee presumably uses WM to maintain an orientation toward the experimental apparatus and to bring behavior back on task when normal attentional lapses occur (Zimmermann &

Leclercq, 2002). However, such executive control via WM presumably explains relatively little variance in overall performance since simple measures like simple and choice RT tasks are not difficult and require only stimulus-driven responses. In contrast, EFs might explain the majority of variance in a more effortful, internally mediated rule-based task (e.g., respond to a left or right stimulus with an opposite-side button press [right stimulus with a left button press], or alternate between direct- and opposite-side responses). Such relatively complex tasks cannot be performed in a stimulus-driven fashion because cognitive operations on the stimulus determine the appropriate response and cognitive control of actions are required. Of note, although the distinction between automatic perceptual-motor and executive control processes may be helpful in differentiating these processes, such a distinction is based entirely on reason as opposed to empirical data, and does not imply that the complexity inherent in behavioral endogenous control (i.e., self-regulation) versus exogenous influences (i.e., driven by stimuli) can simply be reduced, or even fully understood, with this distinction. It is hoped that the concurrent validity results of this study can point the way toward future exploration of such construct validity questions.

In this context, four ECTs were designed: Two putative direct-response tasks (simple and choice RT tasks) and two putative executive control tasks (1- and 2-bit IR tasks). Similar to traditional simple and choice RT tasks, the direct-response tasks presumably require an automatic, perceptual-motor response to a tangible external stimulus. Contrarily, the 1- and 2-bit IR tasks require responses determined by intangible internal rules that are presumably recursive, or self-referential, in the service of executive control. In other words, the internal-rule tasks are operationalized as the ability to self-regulate behavior according to internal rules. Specifically, the 1-bit IR task requires one decision according to an internal rule: making a response to the opposite side of the presenting stimulus. The 2-bit IR task requires making a response on the same side as the presenting stimulus on trial n-1 followed by an opposite side response on trial n. In the latter task, the examinee is to keep alternating same- then opposite-side responses throughout the task, thus requiring two internal rules to perform: make a decision to do a same-side response or an opposite-side response, compare trial n to trial n-1, and do the opposite rule (i.e., do same-opposite-same-opposite responses and so forth throughout the task). Importantly, the self-repeating pattern inherent to the 2-bit IR task is defined by the rules, but applying the rules requires keeping track of how the rules are being applied, giving the task a recursive nature. Thus, one presses a button on the same or opposite side as the stimulus depending upon an alternating pattern, such that one has to keep track of each trial relative to the prior trial. Presumably, this recursive nature is the reason the internal-rule tasks require greater RTs as the number of rules governing responses increases from one to two rules. Overall, the four putative ECTs might differentiate relatively obligatory and automatic cognitive processes assumed to rely on perceptual-motor abilities from controlled, effortful cognitive processes assumed to be supported by EFs. Importantly, such differentiation might shed light on whether EFs are qualitatively different from perceptuomotor skills.

The four ECTs offer several advantages compared to complex EF tasks or paper-and-pencil psychometric instruments. An advantage offered by the ECTs is that task complexity is defined according to information theory, which provides a mathematical specification for each task. Based on information theory, a bit represents the amount of information required to reduce uncertainty by half (Shannon & Weaver, 1963). According to Hick's (1952) Law, the amount of time taken to process a bit is known as the rate of gain of information expressed by the following formula: $\log_2 n$ where n is the number of choices presented. The Hick's law has a logarithmic form because the examinee, presumably using a perceptual process, eliminates half of the remaining choices with each bit, thus yielding a linear time increase with each successive bit of information required (Jensen, 1987). This has been shown in past work using simple and choice RT tasks (Hick, 1952; Jensen, 1987, 2006; Jensen & Munro, 1979), such as the Jensen Box (Jensen, 1987), which may require up to three bits of information when using all response buttons. Specifically, using Hick's law, a precise linear fit to RT data (i.e., about a 27 ms/bit increment) for 0-bit (one response button) to 3-bit tasks (eight response buttons) strongly predicted RT behavior, explaining 97% of the variance in RT in college students (Jensen, 1987, 2006). Such a procedure also maps onto the purported executive control ECTs since each internal rule would reduce uncertainty by half. In the prior example, an internal rule that controls behavior through the verbal statement: "respond with the button opposite the stimulus," requires one bit to reduce uncertainty. A second bit would be added with another internal rule: "alternate from a same-side response to an opposite-side response with each trial." Importantly, and in contrast with simple and choice RT tasks, performance on the internal-rule tasks would be slower, showing a non-linear slope with greater "processing times" with each successive bit. In other words, the linear increment (about 27 ms/bit) in RT across the direct-response tasks of increasing difficulty would not hold for the 1- and 2-bit IR tasks, thus requiring more processing time. In this particular case, it may also permit description and delineation of the elusive construct of EFs, by distinguishing them from perceptual-motor processes. Such predictive relationships would presumably compare favorably to the measurement error of complex, traditional EF tasks (e.g., WCST; Burgess, 1997) or paper-and-pencil psychometric instruments (e.g., Wechsler intelligence scales; Rao & Sinharay, 2007). Another advantage is the four ECTs' flexible computerized platform that may be used and adapted to verbal/nonverbal modalities for patients who may have deficits in either modality or in right/left prefrontal functioning. Such flexibility may presumably be helpful in delineating conflict in the literature regarding laterality of prefrontal functioning. Additionally, patients, who may have either verbal or spatial deficits that compromise their assessment through a specific cognitive modality, could potentially benefit from having complementary tasks that can be adjusted to their intact cognitive abilities (Lezak, 2012). In sum, defining ECTs using information theory (i.e., mathematically) in an attempt to distinguish executive control (i.e., behavioral self-regulation as conceptualized above) from perceptuomotor processes may not only better delineate and measure more precisely such processes, but also allow the use of complementary tasks that can be adjusted according to the patients' intact cognitive abilities.

To date, several unpublished and preliminary studies using the four ECTs have shown results consistent with the previously mentioned predictions about the linear versus nonlinear increase in RT in direct-response versus internal-rule task performances, respectively (Santos, 2014; Santos, Cadavid, Giese, Londono, & Osmon, 2013a; Santos & Osmon, 2012a, 2012b; Santos, Park, Kennedy, Giese, & Osmon, 2013b; Santos et al., 2014, 2015). Overall, results showed a simple increase in RT on the direct-response tasks similar to the performance on both simple and choice RT tasks using the Jensen box, thus following fairly closely the 27ms/bit linear increase found in prior literature using a sample of college students (Jensen, 1987, 2006). A nonlinear slope associated with the 1- and 2-bit IR tasks compared to the direct-response tasks was also found (Santos, 2014). Other studies showed no significant administration order effect of the four ECTs, indicating that specific task performance is not explained by performance on other ECTs (Santos et al., 2013b). Importantly, both the linear versus nonlinear increase in RT and lack of administration order effect have been replicated in culturally different samples (Santos & Osmon, 2012b; Santos et al., 2013a). Taken as whole, these preliminary and unpublished results suggested that the internal-rule tasks are seemingly qualitatively different from the direct-response tasks and provided proof-of-concept for the executive nature of 1- and 2-bit IR tasks. Despite that, the four ECTs have not yet been administered along with executive control tasks commonly used in neuropsychological assessment (e.g., D-KEFS) to determine their relationships and the ECTs' presumably differential contributions to relatively basic EFs (i.e., Shifting, Updating, and Inhibition).

The present study

The purpose of the current study was to examine the concurrent validity of four computerized ECTs by comparing them with specific D-KFES scores in college students. First, both traditional RT and curve-fitting analyses of the ECTs were conducted to ensure replication of previous findings in preparation for the concurrent validity portion of the study. Second, principal component analysis using specific D-KFES scores, which have shown to load on Miyake et al.'s (2000; as cited in Latzman & Markon, 2010) three-factor model of EFs, was performed to ensure the current data were appropriate to test concurrent validity of the ECTs. Finally, hierarchical regression analyses were performed to identify EF components (Shifting, Updating, and Inhibition) of the ECTs as measured by specific D-KEFS scores.

Hypotheses

This study has the following hypotheses:

1. Consistent with Latzman and Markon's (2010) findings, it was expected that Miyake et al.'s (2000) three-factor model of EFs would be found among the D-KFES scores selected a priori; this would ensure such scores were suitable to determine the concurrent validity of the ECTs. Specifically, the Verbal Fluency Test's Category Switching Total and Category Switching Accuracy scores would define the Updating factor; the Color-Word Test's Inhibition and

Inhibition/Switching scores would define the Inhibition factor; and the Sorting Test's Free Sorting, Free Sorting Description, and Sort Recognition scores would define the Shifting factor.

2. Given that an internal representation of the rule(s) and executive control guiding correct responding are prime components of the internal-rule tasks, it was expected that the D-KEFS factor scores would show stronger relationships to the internal-rule tasks compared to the direct-response tasks. Specifically, the following was hypothesized:

2.1. Since EFs are operative in any cognitive task, especially attention-demanding tasks such as RT tasks, small relationships may be detected between the D-KEFS factor scores and the direct-response tasks. While direct precedent literature was not available, based upon models of WM (e.g., Baddeley's [1986, 2000] model of WM) it was expected that behavior is guided by an overriding mental representation or "mental set" held in WM. Thus, it was predicted that Updating would be most related to the direct-response tasks, while Shifting and Inhibition aspects of EF would not be expected to predict direct-response task performance.

2.2. Based upon inferences regarding task design, although again direct precedent literature was not available, it was expected that the internal-rule tasks would include a WM component (Updating) similar to the direct-response tasks. While an overriding mental set would be important in the direct-response tasks, it was expected that this component may be less predictive of internal-rule task performance because of the latter tasks having greater Shifting and Inhibition requirements. For example, Inhibition may be more operative in the 1-bit IR task, since it explicitly requires deliberate control of a prepotent response in favor of a less automatic response (i.e., doing an opposite side response to the presenting stimulus). On the other hand, Shifting may be more predictive in the 2-bit task because of the need to switch the mental set guiding responses across trials (i.e., switching same- and opposite-side responses throughout the task).

Methods

Participants

Participants were recruited via SONA Systems (an online participation tool) in exchange for extra-credit. Participation was voluntary and in accordance with university regulations regarding human research subjects. Inclusion criteria included enrollment in a Psychology course offering extra credit and being 18 years or older. Exclusion criteria included those with English as a second language (ESL) scoring 0.5 standard deviation (*SD*) below the mean performance on the predetermined D-KEFS scores compared to native English speakers, as well as self-reported history of neurological and/or psychiatric conditions, except for those allegedly treated currently for ADHD, mood and/or anxiety disorders. Of the 198 available participants, 23 participants were eliminated after preliminary analyses revealed ESL effects on the D-KEFS subtests, leaving a total of 175 participants. Among the eligible participants, 141 did not report any previous or current psychiatric or neurological condition; 23 had a diagnosis of mood and/or anxiety disorders and were currently medicated; and 11 had a diagnosis of ADHD and were currently medicated (see Table 1). There were no significant differences between participants with and without a psychiatric condition regarding age, gender, handedness, and education.

Materials

The demographics questionnaire (see Appendix A) was administered by the research assistants and included questions about age, date of birth, gender, handedness, education, primary language, and family size; personal and family psychiatric and neurological histories; and current medications and vision problems.

The four ECTs were programmed using Direct RT Research Software (Jarvis, 2008). The stimulus presented in each task consisted of a black circle randomly appearing either on the right or left side of a box centered on a white background, except for the 2-bit IR task, which has a pseudo-random order. Specifically, the simple RT task is a traditional simple RT task that requires pressing the space bar key when either a left- or right-sided circle appears. The choice RT task required a direct response by doing a same-side response to the circle by pressing a left- or right-sided key. Contrarily, the 1-bit IR task required one decision according to an internal rule: doing an opposite-side response to the circle by pressing a left- or right-sided key. The 2-bit IR task required a same-side response to the circle followed by an opposite-side response and alternating these response types throughout the task, thus requiring two internal rules. Each task has 20 practice trials and 120 testing trials except for the simple RT task, which has 5 practice trials. Feedback upon incorrect responses was given during all practice trials and also during testing trials on the 2-bit IR task to help the participant get back on track with the alternating pattern.

The D-KEFS (Delis et al., 2001a) is a psychometrically sound neuropsychological battery co-normed on a large and representative national sample and designed to detect even mild forms of executive dysfunction in children and adults (ages of 8 to 89). Specifically, the Verbal Fluency Test (VFT), a modification of the Controlled Oral Word Association Test (Benton & Hamsher, 1976), measures fluent productivity in the verbal domain by having the participant say words that begin with a specified letter (Letter Fluency); say words that belong to a designated semantic category (Category Fluency); and alternate between saying words from two different semantic categories (Category Switching). The Color-Word Interference Test (CWT) is a variant of the Stroop (Stroop, 1935), measuring inhibition of an overlearned response. On the CWT, the participant is asked to name color patches (Condition 1); read words that denote colors printed in black ink (Condition 2); name the ink color in which color words are printed (Condition 3); and switch back and forth between naming the dissonant ink colors and reading the conflicting words (Condition 4). Finally, the Sorting Test (ST), a version of the California Category Sorting Test (Delis, Squire, Bihrle, & Massman, 1992), measures cognitive flexibility and is composed of two conditions: Condition 1 (Free Sorting) requires the participant to sort six cards into two groups according to as many rules as possible, and Condition 2 (Sort Recognition) requires the participant to identify and describe the correct rules the examiner used to generate the sort. The validity of these subtests has also been demonstrated in numerous neuropsychological studies (Lezak, 2012; Strauss, Sherman, & Spreen, 2006).

Procedures

Participants were screened and tested individually at the Adult Neuropsychology Research Laboratory in accordance with an IRB-approved protocol and methods were consistent with previous unpublished and preliminary studies conducted in our laboratory using the ECTs (Santos, 2014; Santos & Osmon, 2012a; Santos et al., 2014, 2015). Specifically, participants received an informed consent document (see Appendix B) to read and sign, and were allowed to ask the undergraduate research assistants (RAs) questions about the nature of the experiment. Participants then completed a demographics questionnaire with the help of RAs. Participants were administered the four ECTs as follows: simple RT task, choice RT task, 1-bit IR task, and 2-bit IR task. The number of mistaken responses (accuracy), mean RT of correct responses (from target onset until participant's response), and the RT*SD* of correct responses were measured. The ECTs were administered on a desktop computer with an 18-inch monitor and a standard keyboard positioned in a standardized distance of 5 inches from the edge of the table. The three

D-KEFS subtests were administered as follows: CWT, VFT, and ST. The experiment took approximately an hour and extra-credit was given upon testing completion. Data were initially entered into a Microsoft Excel (Microsoft Office Professional Plus 2016, Version 16.0.4266.1003) database and double-checked by RAs in order to eliminate keying errors before conducting statistical analyses. Data transformations and parametric statistical analyses were conducted in SPSS (IBM Corp. 2015, Version 23). In order to conform to traditional RT methods, analyses used a culled distribution with correct responses (≥ 150 ms [physiological limit] and < 2 *SD* above the ipsative mean). Incorrect responses (< 150 ms or contrary to instructions) were examined separately for error analysis.

Results

Table 1 shows the demographic characteristics and descriptive information for this sample. In order to examine differences in ECT performance based on gender and handedness, independent sample *t*-tests were conducted (see tables 2 and 3). One-way analyses of variance (ANOVA) were also conducted to determine whether there were either age differences in ECT performance or differences in ECT performance based on self-reported psychiatric conditions (see tables 4 and 5). Both *t*-test and ANOVA results showed no statistically significant differences in ECT performance based on age, gender, handedness, or self-reported psychiatric condition. Of note, given the main purpose of the current concurrent validity study and that ECT performances between gender and age groups were not significantly different, further group comparisons based on the variables listed in Table 1 were not pursued (see future directions section).

Table 1

Demographic Characteristics and Self-reported Psychiatric Conditions

Variable	*M* (*SD*)
Age	22.24 (4.52)
Education	13.77 (1.50)
Gender (% female)	74.3
Ethnicity (% Caucasian)	66.3
(% African American)	17.7
(% Hispanic)	6.9
(% Asian/Pacific Islander)	5.1
(% Native American)	0.6
(% Biracial/Multiracial)	3.4
Handedness (% Right-handed)	89.1
Anxiety/Mood (%)	13.1
ADHD (%)	6.3

Note. N = 175. Anxiety/Mood = Participants who self-reported diagnosis of anxiety and/or mood disorders and were currently medicated; ADHD = Participants who self-reported diagnosis of attention deficit hyperactivity disorder and were currently medicated.

Table 2

ECT Performance by Gender

ECTs	Male *M* (*SD*)	Female *M* (*SD*)	*Levene F* (*p value*)	*t* (*p value*)	*d*
Simple RT	298.34 (46.78)	307.29 (37.52)	4.892 (.028)	-1.159 (.251)	-0.21
Choice RT	323.58 (37.81)	328.15 (37.75)	.856 (.356)	-.728 (.468)	-0.12
1-bit IR	374.75 (50.27)	385.35 (49.54)	.000 (.996)	-1.233 (.219)	-0.21
2-bit IR	912.34 (199.64)	934.50 (185.64)	1.240 (.267)	-1.187 (.089)	-0.11

Note. ECT = Elementary cognitive tasks. Male (n = 45); Female (n = 130); df = 173.

Table 3

ECT Performance by Handedness

ECTs	Right-handed *M* (*SD*)	Left-handed *M* (*SD*)	*Levene F* (*p value*)	*t* (*p value*)	*d*
Simple RT	306.65 (40.84)	291.34 (31.67)	2.061 (.153)	1.576 (.117)	0.42
Choice RT	327.68 (36.58)	321.21 (33.62)	.074 (.786)	.734 (.464)	1.18
1-bit IR	384.97 (49.20)	363.39 (51.88)	.122 (.727)	1.795 (.074)	0.43
2-bit IR	922.33 (201.37)	861.33 (125.55)	7.241 (.008)	1.848 (.074)	0.36

Note. ECT = Elementary cognitive tasks; Right-handed participants (n = 156); Left-handed participants (n = 19); df = 173.

Table 4

One-Way ANOVA Results with ECT Performance by Age Ranges

ECTs	Ages	*M* (*SD*)	Source	SS	MS	*F*	*p*
Simple RT	18-23	301.72 (38.98)	Between Groups	7661.975	2553.992	1.600	.191
	24-29	317.60 (41.51)	Within Groups	272906.995	1595.947		
	30-35	322.89 (63.90)	Total	280568.970			
	36-44	304.31 (22.53)					
Choice RT	18-23	325.67 (37.32)	Between Groups	1269.318	423.106	.318	.812
	24-29	331.85 (31.40)	Within Groups	227191.133	1328.603		
	30-35	335.06 (44.10)	Total	228460.450			
	36-44	326.96 (27.61)					
1-bit IR	18-23	382.48 (48.99)	Between Groups	6032.621	2010.874	.808	.491
	24-29	377.74 (54.16)	Within Groups	425477.183	2488.171		
	30-35	378.35 (58.29)	Total	431509.804			
	36-44	412.27 (40.35)					
2-bit IR	18-23	911.62 (191.46)	Between Groups	224294.277	74764.759	1.995	.117
	24-29	923.29 (211.23)	Within Groups	6408101.067	37474.275		
	30-35	812.62 (213.90)	Total	6632395.344			
	36-44	1077.32 (118.68)					

Note. ANOVA = Analysis of variance; ECT = Elementary cognitive Tasks; Ages 18-23 (n = 136), 24-29 (n = 27), 30-35 (n = 6), 36-44 (n = 6); df = 3,171.

Table 5

One-Way ANOVA Results with ECT Performance by Participants with and without Self-reported Psychiatric Conditions

ECTs	Group	*M* (*SD*)	Source	SS	MS	*F*	*p*
Simple RT	Control	304.05 (41.03)	Between Groups	599.409	299.705	.184	.832
	Anx/Mood	308.69 (36.53)	Within Groups	279969.561	1627.730		
	ADHD	308.49 (39.51)	Total	280568.970			
Choice RT	Control	326.75 (38.18)	Between Groups	306.991	153.496	.116	.891
	Anx/Mood	326.02 (26.76)	Within Groups	228153.459	1326.474		
	ADHD	331.10 (31.27)	Total	228460.450			
1-bit IR	Control	383.26 (52.38)	Between Groups	1529.709	764.855	.306	.737
	Anx/Mood	384.10 (30.24)	Within Groups	429980.095	2499.884		
	ADHD	371.27 (54.17)	Total	431509.804			
2-bit IR	Control	921.05 (198.43)	Between Groups	98408.644	49204.322	1.295	.276
	Anx/Mood	926.16 (165.43)	Within Groups	6533986.700	37988.295		
	ADHD	824.40 (210.66)	Total	6632395.344			

Note. ANOVA = Analysis of variance; ECT = Elementary cognitive tasks. Control = Participants (n = 139) who reported no current or past psychiatric or neurological conditions; Anx/Mood = Participants (n = 25) who self-reported diagnosis of anxiety and/or mood disorders and were currently medicated; ADHD = Participants (n = 11) who self-reported diagnosis of attention deficit hyperactivity disorder and were currently medicated; df = (2,172).

Table 6

ECT Group Performance

ECTs	Mean (*SD*) RT	Mean (*SD*) errors
Simple RT Task	304.99 (41.2)	0.35 (1.07)
Choice RT Task	326.97 (37.17)	1.95 (2.05)
1-bit IR Task	382.63 (51.1)	4.15 (4.97)
2-bit IR Task	915.70 (195.24)	4.62 (7.92)

Note. ECTs = Elementary cognitive tasks; RT = Reaction time; *SD* = Standard Deviation. RT means and *SDs* are based on correct responses and are given in milliseconds, whereas error means and *SDs* indicate incorrect responses and are given in numeric values.

Table 6 shows basic group-level descriptives on the ECTs based on trimmed data (i.e., RT ≥ 150 ms or < 2 *SD*); less than 5% of the data were trimmed. Evident in Table 2 is the 22ms/bit difference between the direct-response (simple and choice RT) tasks, while the difference between the more complex direct-response (choice RT) task and the simplest internal rule (1-bit EF) task is much greater at 56ms/bit. Likewise, the difference is even greater between the internal-rule (1- and 2-bit EF) ECTs at 533ms/bit. Overall number of errors per task suggests that the ECTs are generally easy when given practice trials with feedback, with only 1.15 and 4.39 errors on average in 120 trials on the direct-response and internal-rule tasks, respectively, which is consistent with previous unpublished findings (Santos, 2014; Santos & Osmon, 2012a, 2012b; Santos et al., 2013a, 2013b).

Figure 1 shows a comparison between the participants' performance on the four ECTs and previous results from the literature using the Jensen Box in college students (e.g., 300 ms for the 0-bit, 324 ms for the 1-bit, 355 ms for the 2-bit and 381 ms for the 3-bit using the Jensen Box in college students; Jensen, 1987). According to Welch's *t*-tests, there were no significant differences in the simple RT task and the 0-bit Simple RT task using the Jensen Box, $t(20.32) = 0.66$, $p < .5176$, as well as in the choice RT task and the 1-bit Choice RT task using the Jensen Box, $t(14.79) = 0.43$, $p < .6702$.

A linear fit to the four ECTs' data was significant and accounted for approximately 60% of the variance (RT = 10.6264 + 188.7795*Task, $F[1,698] = 1047.741$, $p < .0001$). However, adding a quadratic component significantly improved the fit and accounted for an additional 22% of the variance (RT = -149.0901 + 188.7795*Task + 127.7732* Task^2, $F[2,697] = 1588.954$, $p < .0001$), such that a total of approximately 82% was explained by both linear and quadratic components (see Figure 2a). Additionally, a polynomial curve fitting using the direct-response tasks and the 1-bit IR task was run to examine whether the latter added a nonlinear component to the curve. This analysis showed that a linear fit was significant explaining approximately 34% of the variance (RT = 260.5628 + 38.8177*Task, $F[1,523] = 269.5498$, $p < .0001$), while a quadratic term was also significant explaining another approximately 3% of variance (RT = 249.3427 + 38.8177*Task + 238.7163* Task^2, $F[2,522] = 147.7167$, $p < .0001$) (see Figure 2b). Figure 2c shows the choice RT task followed by the 1- and 2-bit IR tasks compared for RT. The linear curve fit the data with approximately 68% of the variance explained (RT = -341.3223 + 294.3641*Task, $F[1,523] = 1134.937$, $p < .0001$), but the quadratic curve fit better explaining approximately 83% of the variance (RT = -500.4665 + 294.3641*Task + 238.7163*Task^2, $F[2,522] = 1317.106$, $p < .0001$). Given the wide range of variability on the 2-bit IR tasks, participants were divided into quartiles to compare the best performers to the worse performers. Figure 2d shows the first three tasks (simple RT, choice RT, and 1-bit EF) compared to the fourth task (2-bit EF) broken into participants by quartiles based upon RT. Evident was the continuing nonlinear nature of the curve even in most of the best performers on the 2-bit IR task. Specifically, there was little overlap between the distributions of the internal-rule tasks, suggesting qualitatively different performance. Likewise, the linear curve fit the data with approximately 86% of the variance explained (RT = 67.1105 + 144.4739*Task, $F[1,697] = 4894.628$, $p <.0001$), but the quadratic curve fit better explaining approximately 94% of the variance (RT = 102.2279 + 109.8633 *Task + 20.6949*Task^2, $F[2,696] = 5067.424$, $p < .0001$).

Individual subject data were analyzed to determine the penetrance of the nonlinear results. Visual analysis of all 175 participants showed that the nonlinear relationship between the ECTs held strongly for every subject, except for participant 40 despite having fewer errors in the internal-rule tasks when compared with the group's mean errors for each task. Individual

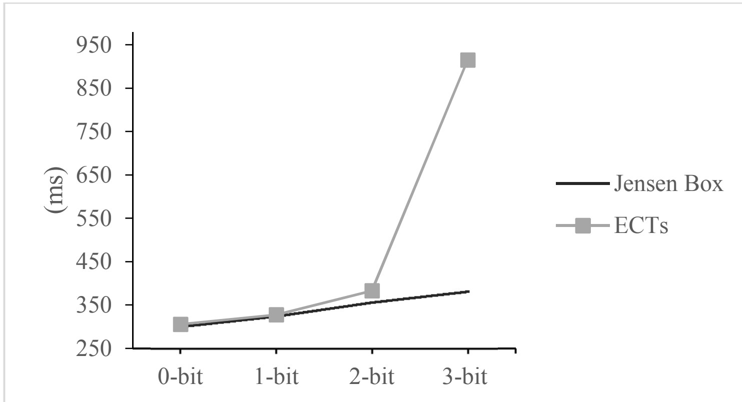

Figure 1. Comparison between participants' performance on the four ECTs and previous results from the literature (Jensen, 1987). The X axis shows results in bits using the Jensen Box, which correspond with the simple and choice RT tasks followed by the 1- and 2-bit IR tasks, respectively.

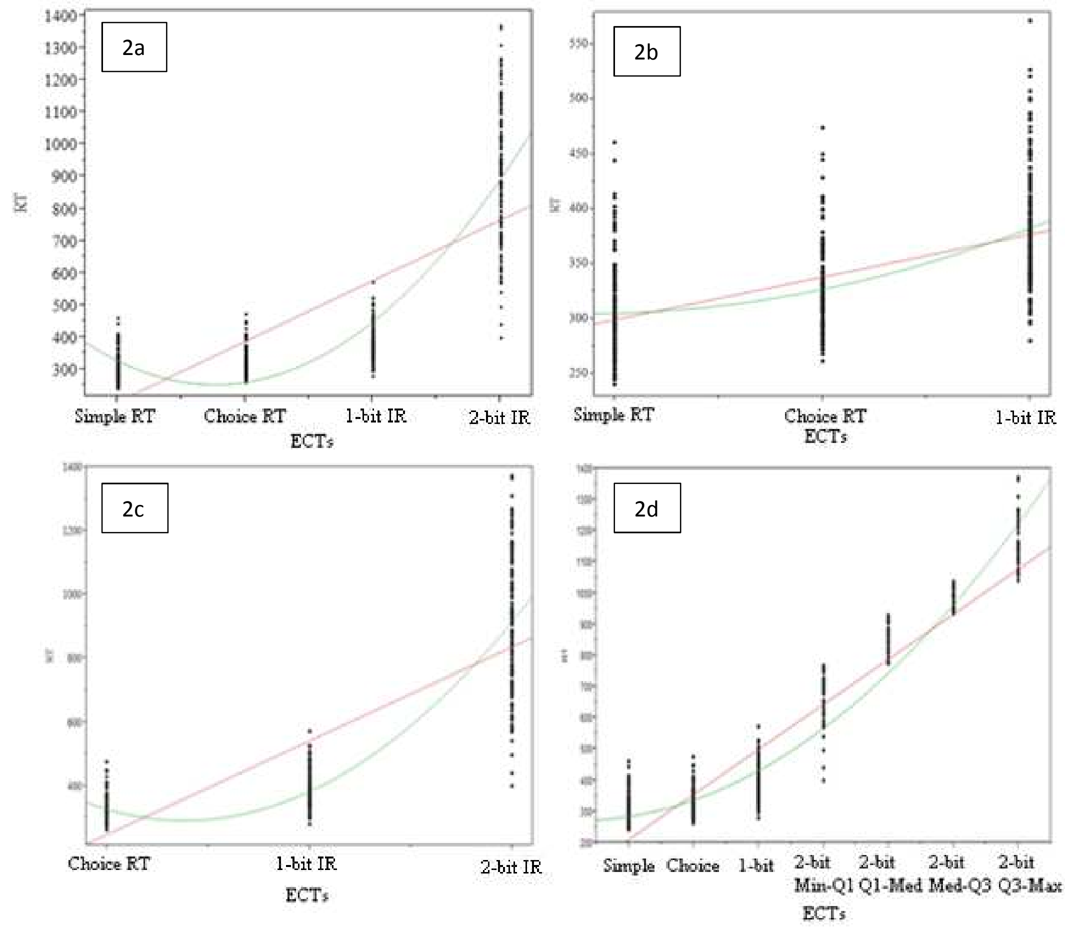

Figure 2. (a) Linear and quadratic curve fitting the four ECTs. (b) Linear and quadratic curve fitting the direct-response tasks compared to the 1-bit IR task. (c) Linear and quadratic curve fitting the choice RT task with the internal-rule tasks. (d) Linear and quadratic curve fitting the simple RT, choice RT, and 1-bit IR tasks compared to the 2-bit IR task broken into quartiles based upon RT.

variation in the magnitude of the nonlinear relationship was evident, with a few participants showing extreme increases in RT from the 1-bit IR to the 2-bit IR tasks, while a few others showed much less, yet still, nonlinear increases (e.g., participants 42 and 57) (see Figure 3).

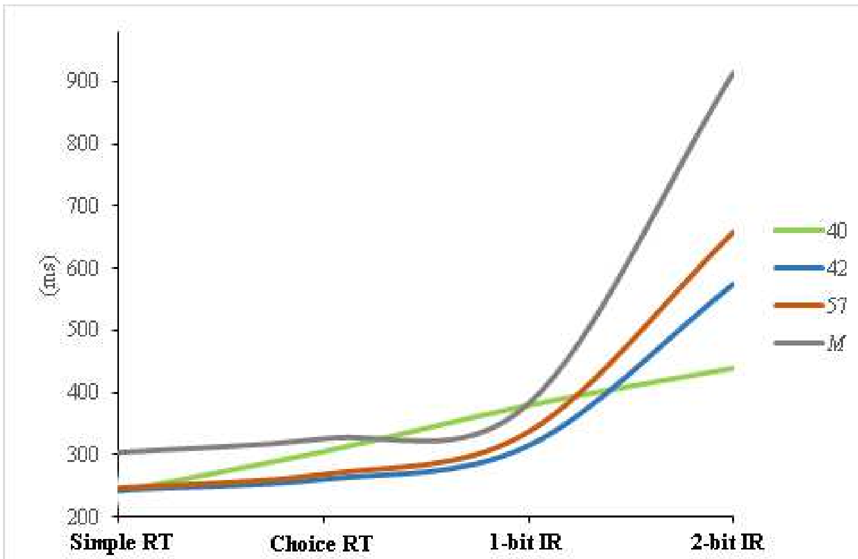

Figure 3. Individual ECT performance for participants 40, 42, and 57 is compared to group average performance on the ECTs.

Hypothesis 1

To answer hypothesis 1, which predicted that a three-factor model would best fit the predetermined D-KFES scores, the scores were subjected to principal component analysis (PCA). Since PCA encourages maximal loading of all variables on the first factor, this method seemed most appropriate to the general ("common EF") factor. Prior to performing PCA, the assumptions of normality, linear relationships between pairs of variables, and correlation values among variables were checked along with the suitability of data for factor analysis.

Shapiro Wilk's (W) tests ($p < 0.05$) for normality were performed and indicated significant differences from the standard normal distribution. Several transformations were attempted and a two-step approach (Templeton, 2011) was selected, producing normally distributed scores for

VFT and ST's Sort Recognition, and approximately normally distributed scores for CWT's Inhibition and Inhibition/Switching as well as for ST's Free Sorting and Free Sorting Description, with tolerable skewness and kurtosis values. The assumption of linearity was met based on the matrix scatterplots, and inspection of the correlation matrix revealed the presence of many coefficients of .3 and above. The Kaiser-Meyer-Olkin value was .65, exceeding the recommended value of .6 (Kaiser 1970, 1974) and Bartlett's Test of Sphericity (Bartlett, 1954) reached statistical significance ($\chi 2$ [21] = 806.991, $p < .0001$), confirming the factorability of the correlation matrix. The communalities were all above .3, further confirming that each score shared some common variance with other items. Although the inspection of the scree plot showed a break after the fourth component, the PCA revealed the presence of three components with eigenvalues exceeding 1, explaining 45.5%, 22.9%, and 15.8% of the variance, respectively. In other words, the three-factor model accounted for a total of 84.2% of the variance. The fourth, fifth, sixth, and seventh factors had eigenvalues less than 1, explaining 7.8%, 5.4%, 1.3%, and 1.2% of the variance, respectively. Using Kaiser's (1960) eigenvalue-greater-than-one rule, it was decided to retain three components for further investigation. This was supported by the results of Parallel Analysis, which showed only three components with eigenvalues exceeding the corresponding criterion values for a randomly generated data matrix of the same size (7 variables × 175 participants). To aid in the interpretation of these three components, Varimax rotation was performed to examine theoretically independent dimensions of executive functions and identify the factors that underlie the predetermined D-KEFS scores in our sample. The rotated solution revealed a number of strong loadings on the three components, with ST's scores loading on Component 1 (Shifting), VFT's scores on Component 2 (Updating), and CWT's scores on Component 3 (Inhibition) (see factor loading matrix in Table 7) consistent with previous empirical support (Latzman & Markon, 2010). No scores were eliminated because they all contributed to the factor structure and did not have cross-loadings of .3 on any factor. In sum, the results of the PCA replicated the D-KEFS' factor structure and supported the use of these three components as separate factors to investigate the constructs underlying the ECTs as described next.

Hypothesis 2

Hypothesis 2 predicted that D-KEFS factors would show stronger relationships to the internal-rule tasks compared to the direct-response tasks, with Updating being most related to the latter tasks and with Shifting and Inhibition being most predictive of the former tasks. To answer Hypothesis 2 and after the factor structure of the D-KEFS was replicated suggesting a three-factor model as described by Latzman and Markon (2010) in the current data, regression factor scores were calculated for each factor per participant. Factor scores were used in the follow-up hierarchical regression analyses to investigate the capability of the factors in predicting performance on the four ECTs. Preliminary analyses were conducted to ensure no violation of the relevant assumptions of multiple regression. Shapiro Wilk's (W) tests ($p < 0.05$) for normality were performed on the three D-KEFS factor scores and the ECTs' trimmed RT data ($\geq$ 150 ms or < 2 *SD*). Results indicated significant differences from the normal distribution in both direct-response tasks and 1-bit IR task, but not in the 2-bit IR task or the D-KEFS factor scores. A two-step transformation approach (Templeton, 2011) was also conducted, producing normally distributed RT distributions for both direct-response and the 1-bit IR tasks. Given that the independent variables (factor scores) were composed of achievement total scores and not a combination of subscale scores and total score(s) of a scale, the assumption of singularity was deemed to have been met. An examination of correlations revealed that no independent variables were highly correlated. As the collinearity statistics (i.e., Tolerance and VIF) were all within accepted limits, the assumption of no multicollinearity was deemed to have been met (Coakes, 2005; Hair et al., 1998). Residual and scatterplots indicated the assumptions of linearity and homoscedasticity were satisfied (Hair et al., 1998; Pallant, 2001).

As the basis of concurrent validity, correlation coefficients were computed among the four ECTs and the D-KEFS factor scores. Using the Bonferroni approach to control for Type I error across the 21 correlations, a p value of less than 0.0023 ($.05/21 = .0023$) was required for significance. The results of the correlational analyses are presented in Table 8. Sixteen of the 21 correlations were statistically significant and were greater than or equal to .24. A large correlation was seen between the simple and choice RT tasks as well as between the choice RT and 1-bit IR tasks. Moderate correlations were seen between the internal-rules tasks as well as between the direct-response tasks and the IR tasks. Several negative correlations between the D-KEFS factor scores and the ECTs were also seen. Specifically, Inhibition was shown to moderately correlate with the four ECTs; Updating was shown to have low significant correlations with the direct-response tasks; and Shifting had a low significant correlation with the 2-bit IR task. In other words, correlations between speed (ECTs) and power (D-KEFS) tasks were apparent only for Inhibition across the ECTs, whereas Updating and Shifting approached the lower limit of typical correlations for the direct-response tasks and for the 2-bit IR task, respectively. Correlations between the D-KEFS factor scores were low to moderate and all significant, which is consistent with prior results in a similar age sample (Latzman & Markon, 2010). In general, the results suggest that the quicker the participants' RT on the ECTs, the better their scores are on the D-KEFS scores.

Two-step hierarchical multiple regressions were conducted with each of the four ECTs (dependent variables), entering the Updating factor at Step 1 of the regression to control for WM, while the Inhibition and Shifting factors were entered at Step 2. Results showed that at Step 1, Updating contributed significantly to regression models including the direct-response tasks but not to regression models including the internal-rule tasks, and explained 4.5% of the variance in the simple RT task ($F[1,173] = 8.240$, $p < .005$), 5% in the choice RT task ($F[1,173] = 9.142$, $p < .001$), 2% in the 1-bit IR task ($F[1,173] = 3.468$, $p < .064$), and 0.2% in the 2-bit IR task ($F[1,173] = .258$, $p = .612$). Adding Inhibition and Shifting at Step 2 significantly explained an additional 7.9% of the variance in the simple RT task (F change $[2, 171] = 7.763$, $p < .001$), 9.3% in the choice RT task (F change $[2,171] = 9.279$, $p < .0001$), 11.4% in the 1-bit IR task (F change $[2,171] = 11.257$, $p < .0001$), and 22.6% in the 2-bit IR task (F change $[2,171] = 24.955$, $p < .0001$). Thus, the total variance explained by each regression model as a whole was 12.5% in the simple RT task ($F[3,171] = 8.137$, $p < .0001$), 14.3% in the choice RT task ($F[3,171] = 9.525$, $p < .0001$), 13.4% in the 1-bit IR task ($F[3,171] = 8.798$, $p < .0001$), and 22.7% in the 2-bit task ($F[3,171] = 16.746$, $p < .0001$). Overall, Updating and Inhibition were statistically significant in the simple RT task, with Inhibition recording higher beta values ($\beta = -.28$, $p < .0001$) than Updating ($\beta = -.21$, $p < .01$); the three D-KEFS factor scores were statistically significant in the choice RT task, with Inhibition recording higher beta values ($\beta = -.26$, $p < .0001$) followed by Updating ($\beta = -.22$, $p < .01$) and Shifting ($\beta = -.16$, $p < .05$); and Inhibition and Shifting were statistically significant for the 1- and 2-bit IR tasks, with Inhibition recording higher beta values ($\beta = -.29$ & $-.44$, $p \leq .0001$, respectively) than Shifting ($\beta = -.18$ & $-.18$, $p \leq .05$ & $.01$, respectively). Table 9 shows regression statistics.

Table 7

Factor Loadings Based on a PCA with Varimax Rotation for Predetermined D-KEFS Scores

D-KEFS Achievement Total Scores	Shifting Factor	Updating Factor	Inhibition Factor
Verbal Fluency: Cat. Switch Total	.16	**.95**	.16
Verbal Fluency: Cat. Switch Accuracy	.10	**.96**	.15
Color–Word Test: Inhibition	.29	.13	**.83**
Color–Word Test: Inhibition/Switching	.01	.17	**.90**
Sorting Cond. 1: Free Sort	**.93**	.06	.09
Sorting Cond. 2: Free Sort Description	**.94**	.14	.07
Sorting Cond. 3: Sort Recognition	**.72**	.14	.19

Note. $N = 175$; Loadings ≥ .50 are given in boldface. D-KEFS = Delis–Kaplan Executive Function System; PCA = Principal component analysis.

Table 8

Bivariate Correlations Among the ECTs and the D-KEFS Factor Scores

ECTs	Choice RT	1-bit IR	2-bit IR	Updating	Inhibition	Shifting
Simple RT	.62*	.42*	.33*	-.25*	-.30*	-.02
Choice RT		.70*	.42*	-.28*	-.31*	-.22
1-bit IR			.43*	-.21	-.33*	.23
2-bit IR				-.11	-.44*	-.24*
Updating					.33*	.24*
Inhibition						.28*

Note. D-KEFS = Delis–Kaplan Executive Function System; ECTs = Elementary cognitive tasks; $N = 175$; $^*p < 0.0023$

Table 9

Summary of Hierarchical Regression Analysis for D-KEFS Factors Predicting ECT Performance

ECTs	*B*	*SE B*	*β*	*t*	Sr^2	R^2	ΔR^2
Simple RT							
Step 1						.045	.045
Updating	-8.562	2.983	-.213	-2.871**	.045		
Step 2						.125	.079
Updating	-8.562	2.873	-.213	-2.981**	.045		
Inhibition	-11.206	2.873	-.279	-3.901****	.078		
Shifting	1.592	2.873	.040	.554	.002		
Choice RT							
Step 1						.050	.050
Updating	-8.118	2.685	-.224	-3.024**	.050		
Step 2						.143	.093
Updating	-8.118	2.565	-.224	-3.165**	.050		
Inhibition	-9.316	2.565	-.257	-3.632****	.066		
Shifting	-5.942	2.565	-.164	-2.317*	.027		
1-bit IR							
Step 1						.020	.020
Updating	-6.982	3.749	-.140	-1.862	.020		
Step 2						.134	.114
Updating	-6.982	3.544	-.140	-1.970	.020		
Inhibition	-14.223	3.544	-.286	-4.013****	.081		
Shifting	-8.976	3.544	-.180	-2.532*	.033		
2-bit IR							
Step 1						.001	.001
Updating	-7.529	14.833	-.039	-.508	.002		
Step 2						.227	.226
Updating	-7.529	13.126	-.039	-.574	.002		
Inhibition	-85.436	13.126	-.438	-6.509****	.191		
Shifting	-36.051	13.126	-.185	-2.747**	.034		

Note. D-KEFS = Delis–Kaplan Executive Function System; ECTs = Elementary Cognitive Tasks; $N = 175$; $*p < .05$, $**p \leq .01$, $***p \leq .001$, $****p \leq .0001$

Discussion

The purpose of the present study was to examine the concurrent validity of four computerized ECTs by comparing them with specific D-KFES scores shown to load on Miyake et al.'s (2000; as cited in Latzman & Markon, 2010) three-factor model of EFs in a sample of college students. Prior to discussing the correlation and regression results that form the basis of the main concurrent validity findings, both traditional RT analyses and curve-fitting procedures were performed to ensure replication of previous findings regarding ECT performances. First, performance on the simple and choice RT tasks is no different from the performance on similar tasks using the Jensen box, following closely the 27ms/bit linear increase found in prior literature using college students (Jensen, 1987). Thus, the direct-response tasks conform to prior work verifying the perceptual-motor nature of the tasks. Second, performance on the 1- and 2-bit IR tasks, requiring internal rules to respond with recursive processing, showed a nonlinear slope associated with each task (56ms/bit and 533ms/bit, respectively). Such nonlinear increase in RT was demonstrated by the increased variance explained by quartic curve fit analyses, and indicates a seemingly qualitative difference with the direct-response tasks due presumably to the executive control nature of the internal-rule tasks. Third, the high penetrance of the results was evidenced by visual inspection, with 174 of 175 participants showing the nonlinear difference between direct-response and internal-rule tasks. Importantly, the nonlinear relationship was not due to wide variation in the 2-bit IR task, as evidenced by the little overlap between the best performers on the latter task (i.e., participants in the first quartile) and overall performance on the 1-bit IR task. In sum, these results replicated previous unpublished findings (Santos, 2014; Santos & Osmon, 2012a, 2012b; Santos et al., 2013a, 2013b, 2014, 2015) and are consistent with greater executive control required in the internal-rule tasks compared to the direct-response tasks.

Regarding hypothesis 1, which predicted that a three-factor model would best fit the predetermined D-KFES scores, present data replicated the D-KEFS factor structure using specific subtests' total achievement scores that had previously shown the highest loadings on Miyake et al.'s (2000; as cited in Latzman & Markon, 2010) three-factor model. These results validated the use of D-KEFS factors as a proxy for the well-established three-factor model of EFs. As a result, correlations and hierarchical regression analyses using the D-KEFS factor scores (i.e., power tests) to predict performance on the four ECTs (i.e., speed tests) provided the most interesting concurrent validity findings related to hypothesis 2.

Hypothesis 2 was the central concern of this study, which was the concurrent validity of the ECTs with the D-KEFS factors. Specifically, we predicted that D-KEFS factors would show stronger relationships to the internal-rule tasks compared to the direct-response tasks, with Updating being most related to the latter tasks and with Shifting and Inhibition being most predictive of the former tasks. In retrospect, the D-KEFS factors, as mainly power cognitive measures (see Carroll, 1993; Jensen, 2006), were probably less suited to test the concurrent validity of the speed measures represented by the ECTs than the speed/accuracy-related measures of Miyake and colleagues' studies (Miyake et al., 2000; Miyake & Friedman, 2012). Specifically, and as noted in a major review by Sheppard and Vernon (2008) of the tried and true speed-power concept of cognitive measures (Kelley, 1927), mental speed measures (e.g., simple and choice RT tasks) load onto a separate factor from power measures (e.g., intelligence tests and specific cognitive tests), and are typically low to moderately correlated (r = -.3 to -.4); therefore, these correlations would define the upper limit for the potential relationships among power and speed measures. From this vantage point, our correlations and regression results find support for the concurrent validity of the ECTs. That is, low to moderate significant correlations were seen between Inhibition and the four ECTs, and not only to the internal-rule tasks as expected. Further, low but significant correlations partially differentiated direct-response and internal-rule tasks. Also, and consistent with prior literature conceptualizing EFs as having a "unitary and diverse" nature (Miyake & Friedman, 2012; Miyake et al., 2000), the interfactor correlations suggest the presence of a "common EF" (Inhibition) factor that is also separable from the lower order factors of Shifting and Updating (Latzman & Markon, 2010).

Regression analyses further showed the combined effects of the D-KEFS and ECTs relationships. First, variance of the ECTs explained by the three D-KEFS factors ranged from approximately 13% to 23%. While the 2-bit IR task was most related to the D-KEFS factors and had the most variance explained, the 1-bit IR task was no more related to the D-KEFS factors than the direct-response tasks. Second, perceptual-motor and executive control processes were not clearly distinguished between the direct-response and internal-rule tasks as hypothesized. Briefly, multiple EF components contributed to even simpler RT tasks and at similar levels to their contribution to the 1-bit IR task as explained in detail below. Also surprising, and similar to the correlation results, was the pervasive influence of Inhibition and the gradation of executive control contributions across tasks. That is, and as predicted, Updating related to the simple and choice RT tasks, but unexpectedly contributed no significant variance to the internal-rule tasks. Furthermore, the simple and choice RT tasks were similar in requiring Updating and Inhibition; however, the choice RT task, unlike the simple RT task, also required Shifting, which was a characteristic of the internal-rule tasks. Finally, the only clear distinction between the internal-rule tasks was the greater variance accounted for by Inhibition in the 2-bit IR task compared to the 1-bit IR task. Overall, the four ECTs differentially contributed to Shifting, Updating, and Inhibition, which again is consistent with the "unity and diversity" of EFs (e.g., Miyake et al., 2000; Miyake & Friedman, 2012) and deserves further discussion.

The fact that Updating, associated with monitoring and evaluating new information in WM, only related significantly to the simple and choice RT tasks may be understood in light of past literature on the fundamental role of WM in executive control (e.g., Baddeley, 1986; Baddeley & Hitch, 1974; D'Esposito et al., 1995; Goldman-Rakic, 1995). Briefly, such theories argue that WM organizes sensory experience into transient representations that allow individuals to hold information in mind for the purpose of higher cognition, such as planning, organizing actions, and problem-solving. For example, Baddeley's (2000) "episodic buffer" allows the coordination of perceptual and executive processes, as may presumably be needed in RT tasks where control of attention to "off-task" stimuli is required, but effortful executive processes need not be fully activated. Therefore, the current results regarding the relationships between Updating and the direct-response tasks suggest that WM, presumably via the episodic buffer, establishes a relevant "mental set" during tasks requiring more perceptuomotor processes than effortful control. This assumption and the reason the internal-rule tasks did not require the updating process should be evaluated in future research.

Compared to Updating, the pervasive influence of Inhibition on the four ECTs is difficult to interpret within the confines of many EF theories assuming that executive control is based upon the organizing influence of WM, as explained previously. This finding suggests that, even in the simplest ECT, holding behavior in check until an action is required is fundamental to performance. It is likely that keeping behavior in check may be particularly important in RT tasks where attention needs to be tightly focused to make rapid responses over an extended period of time. Alternatively, Inhibition may reflect a general facet of all deliberate behavior given that several studies have consistently found that Inhibition is an overarching, general factor in both basic and complex EF tasks (e.g., Fisk & Sharp, 2004; Friedman & Miyake, 2004; Friedman et al., 2006; Hull et al., 2008; Miyake & Friedman, 2012; Miyake et al., 2000; Lazman & Markon, 2010). In any case, further research is necessary to confirm these assumptions as these results may not generalize to other simple or complex EF tasks that do not have the tightly focused, rapid response requirements of RT tasks. Furthermore, whether Inhibition is a general facet of behavior similarly across all tasks, or whether it may have differentiated aspects among the tasks should be further evaluated with ex-Gaussian parameters reflecting the normal versus ‘fat [right] tail’ aspects of the distribution (see future directions).

Shifting was not only a significant predictor of the internal-rule tasks, but also of the choice RT task. Of note, Shifting is generally thought to relate to switching between higher level ‘mental sets’ (i.e., alternating between internal rules when performing; see Ravizza & Carter, 2008; Rogers & Monsell, 1995). This common interpretation of Shifting is challenged by the current results given that the only difference between the simple and choice RT tasks is that the latter requires switching responses between left- and right-sided keys (i.e., switching between motor actions). Therefore, the contribution of Shifting to the choice RT task, but not the simple RT task, suggests an embodied cognition interpretation; that is, Shifting is related to a motor action rather than cognition. As expected, based upon inferences regarding task design, Shifting was less predictive than Inhibition in the1-bit IR task, which explicitly requires deliberate control of a prepotent (i.e., more dominant) same-side response in favor of less preferred and more effortful action of an opposite-side response. Similarly, and contrary to our inferences, Shifting was less predictive than Inhibition in the 2-bit task, which requires switching between same- and opposite-side responses across trials compared to the 1-bit IR task. In fact, performance on the 2-bit task was almost entirely dependent on Inhibition, more so than any other ECT, and was also predicted by Inhibition to a greater degree compared to the other ECTs. This unexpected result warrants further study, especially in regard to differing contributions of Shifting to the *mu* (i.e., mean) and *sigma* (i.e., *SD*) parameters of the Gaussian portion of the RT distribution and to the ex-Gaussian *tau* (i.e., the combined mean and *SD*) parameter of the ‘fat tail’ of the distribution (see future directions).

In summary, previous unpublished and preliminary findings using the ECTs were replicated, but present results did not strongly support D-KEFS factor differentiation among the

ECTs, although typically low to moderate correlations for speed and power tasks were evident, with stronger relationships as the ECTs became more complex. Specifically, results showed a pervasive effect of Inhibition and lesser contributions from Updating and Shifting to ECT performances, which is consistent with a growing body of literature on the unity and diversity of EFs as demonstrated by several factor analytical studies revealing a "common EF" (Inhibition) factor and lower level (Updating and Shifting) factors. Additionally, these results indicate that Updating is more related to simpler RT tasks where more complex attentional control processes (e.g., task switching) are less operative. Finally, Shifting is a minor component of some of these ECTs that comes to light with the choice RT task and other RT tasks of greater complexity like the internal-rule tasks. Clinical and theoretical implications as well as study limitations are discussed next along with suggestions for future directions using the ECTs.

Clinical and theoretical implications

Overall, and despite the relatively small variance explained by the D-KEFS factors, the pervasiveness of Inhibition across the ECTs suggests that these tasks have some common process that includes inhibition. Additionally, we believe these ECTs have several advantages that warrant continued study for several reasons. First, these tasks, as noted by Jensen (1998, see Chapter 8), seemingly have fewer cognitive components compared to complex, power EF tasks (e.g., WCST) or to relatively simple EF speed/power tasks (e.g., Stroop Task); however, this is an assumption that requires further research. Second, task complexity for both direct-response and internal-rule tasks is defined according to information theory (i.e., mathematically). The mathematical specification of bits allows a graded and precise level of difficulty to be developed across tasks that have very similar structures. Third, the ECTs have high construct penetrance given that the nonlinear relationship between direct-response and internal-rule tasks, presumably associated with the executive nature of the latter tasks, was widely applicable to nearly all individuals. Fourth, the ECTs may be used to differentiate inter-individual differences in executive ability, as reflected by current results showing wide-ranging variability across participants; this is an important characteristic when trying to understand cognitive strengths and weaknesses in different individuals and populations (Bech, 2012). Fifth, the ECTs also have the advantage of being delivered via a flexible, computerized platform that may be used and adapted to verbal/nonverbal modalities for patients who may have deficits in either modality or in right/left prefrontal functioning. Sixth, the ECTs can be directly compared to each other since they are measured with high precision given in milliseconds and on a ratio-level scale, making irrelevant the different windows of absolute performance across tasks that are measured on an interval scale. Also, RT data are amenable to non-Gaussian analysis (e.g., ex-Gaussian), which can provide more fine-grained time-course information compared to traditional RT analysis. For example, ex-Gaussian parameters separate the normal Gaussian component from the exponential 'fat-tail' component of the distribution (i.e., *tau*), which is generally considered to reflect "attention lapses" (Hervey et al., 2006; Whelan, 2008) and has been shown to provide valuable clinical information above and beyond traditional Gaussian analyses, with important theoretical implications for the study of executive control processes in different clinical populations (Balotta & Yap, 2011).

Beyond the clinical implications of the present results and the potential advantages of the ECTs, there are significant theoretical implications. First, the pervasive nature of inhibition and the limited influence of WM in the internal-rule tasks argues against a regulatory "mental set" interpretation of EFs in favor of an action control conception. In other words, given the central role of WM in many theories of EFs, and the lack of statistically significant results of Updating across ECTs and the pervasive influence of Inhibition instead, current results suggest that keeping behavior in check is more fundamental for performance on RT tasks. Second, meager correlations between the D-KEFS and ECTs seem to warrant extending the current study by using Miyake et al.'s (2000) original tasks employed to develop the three-factor model of EFs (e.g., letter memory task, antisaccade task, stop-signal task, Stroop task, tone monitoring task, keep track task, local-global task, plus-minus task, and number-letter task), which was dominated mostly by speed tasks. Using such tasks may provide not only better correlations given that they are speed tasks like the current ECTs, but may also better test for differentiation of basic EFs between the 1- and 2-bit IR tasks. For example, it seems unlikely that the greater difficulty of the 2-bit IR task compared to the 1-bit IR task can be accounted for entirely by quantitative differences in Inhibition. Thus, it may be that the EF factors not well represented by the D-KEFS power model compared to the original Miyake et al.'s (2000) three-factor model.

Limitations

Limitations of the present study include sample generalization, the need for administration via a computer, and problems with RT measurements of behavior. Since the sample included only college students in a relatively narrow age range, the external validity of the present results is limited. Nevertheless, attempts were made to also recruit students with common psychiatric conditions (ADHD, anxiety, and mood disorders; Mattern & Ware, 2007) who were currently undergoing treatment, given the known impact of such conditions on EFs (e.g., Darvishzadeh et al., 2012; Nigg et al., 2005; Tandon et al., 2002; Tucker & Derryberry, 1992). Also, the ECTs necessitate computer administration, which limits the practicality of these tasks for clinical use.

There are several restrictions for measuring cognitive processes via RT tasks. First, RT tasks can measure cognitive complexity, as demonstrated by the increasing RT from the simple RT task to 2-bit IR task in this study; however, that measurement is intimately confounded with speed issues that cannot be completely disentangled (Colom, 2009). Therefore, RT tasks are not suitable for all populations, such as patients with motor-sensory disturbance like multiple sclerosis (Flehmig et al, 2007). Second, RT tasks may also suffer from reduced test-retest reliability (Luce, 1986), but having sufficient trials as in the current study (e.g., greater than 100 trials; Hamsher & Benton, 1977) has been found to rectify this difficulty. Finally, RT tasks typically have positively skewed distributions (Luce, 1986), although this limitation can often be moderated by using outlier trimming procedures (Jensen, 2006) and distributional analysis (Whelan, 2008). Regarding the latter, there is a significant body of literature recommending the use of non-Gaussian analysis in RT tasks (e.g., Dawson, 1988; Hervey et al., 2006; Lin, Hwang-Gu, & Gau, 2015; Ratcliff, 1993, 2013; Ratcliff & Childers, 2015; Ratcliff & Rouder, 1998; Ratcliff & Tuerlinckx, 2002; Stewart, 2014; Vaurio, Simmonds, & Mostofsky, 2009; Whelan, 2008), as such analysis preserves the RT distribution, characterizes its shape, and provides information with which to test models and make a clear description of the behavior of interest, potentially avoiding misinterpretation of the data (Heathcote et al., 1991). Although the shape of a RT distribution is often considered to be similar to the ex-Gaussian distribution (Luce, 1986), there are several non-Gaussian distributions (e.g., Gamma, Beta, Weibull, etc.) that may be used to evaluate a given distribution based on theoretical considerations for hypothesis testing (Van Zandt, 2011).

Future directions

The concurrent validity results did not strongly support differentiation of perceptuomotor and executive control among the ECTs and found little differentiated facets of EFs (Inhibition and Shifting) across the internal-rule tasks. Nevertheless, there is reason to explore the latter question further given that the 2-bit IR task is so much more difficult than the 1-bit IR task. For example, it seems unlikely that a simple quantitative difference in Inhibition can account for the greater RTs in the 2-bit IR task. Therefore, future work is needed to understand whether the greater contribution of Inhibition to the 2-bit IR task is qualitatively or just quantitatively different than its contribution to the other ECTs. More work is also necessary to determine whether the internal-rule tasks assess Inhibition specifically beyond general EF requirements of any RT task, especially in the ex-Gaussian component of the distribution. More differentiation of the constructs underlying the explained and unexplained variance of the ECTs can also be explored by applying Ratcliff's (1979) diffusion model (especially using speed rather than power or speed/power tasks) to examine non-executive processes, such as encoding and response time apart from decision time. In particular, researchers should examine boundary separation and drift rate parameters of the diffusion model to better understand differences between the internal-rule tasks. That is, the most difficult internal-rule task (the 2-bit IR task) is likely to require both more conservative boundary conditions to make a decision and greater time accumulating information, as reflected in the drift rate (see Ratcliff & McKoon, 2008). Additionally, different instantiations of the ECT format will be important in establishing the applicability of this format to different EF constructs. As an example, verbal and nonverbal stimuli may be useful to examine for lateralized frontal dysfunction.

Future work should be directed at exploring how the ECTs relate to different inhibitory processes. It seems likely from current results that all tasks requiring fast-paced, closely-spaced responses necessitate some aspect of the Inhibition factor. While inhibition is multi-faceted (e.g., stopping an already programmed action and inhibiting a more automatic response in favor of another response), RT tasks might require suppressing response competition and controlling interference from irrelevant stimuli and responses. Of course, these assumptions warrant further investigation. Furthermore, studies using relatively simple speed tests similar to those employed by Miyake and colleagues (Miyake et al., 2000) should be conducted, as they may reveal higher correlations with the ECTs.

We believe that future research should also address how well the D-KEFS predicts both the Gaussian and non-Gaussian parameters of the four ECTs. Specifically, intra-individual variation, the shape parameter of the LogNormal distribution, and ex-Gaussian parameters (*mu, sigma,* and *tau*) need to be examined. For example, it is important to test whether individuals, not just group data, fit a single distribution model for each of the four ECTs as well as the "attentional lapses" in the *tau* parameter of the ex-Gaussian distribution, which is presumably more indicative of executive difficulties than quicker and more automatic responses in the Gaussian portion of the distribution (Hervey et al., 2006; Ratcliff & Tuerlinckx, 2002; Whelan, 2008). Importantly, it should be noted that while the ex-Gaussian has been the most popular model to fit RT distributions (e.g, Ratcliff, 1979), its fit has been called into question in many cases (see Luce, 1986; Van Zandt, 2011), particularly with small sample sizes. Therefore, it is recommended to test the fit of other distributional models (e.g., LogNormal, Gamma, Weibull) of both the group and the individual participant RT distribution, and to exert caution when interpreting ex-Gaussian results, particularly when sample size is small.

We believe that studies should be focused on comparing cognitively normal individuals with people with a condition(s) typically associated with executive dysfunctions (e.g., ADHD), whose diagnoses have been confirmed by rigorous screening procedures. Furthermore, future investigation of group differences based on demographics and psychiatric/neurological conditions should be pursued. For example, given that current results showed seemingly quicker, although not statistically significant, performances on the 1- and 2-bit IR tasks between participants who self-reported ADHD versus other participants as well as mixed effects models looking also at potential interactions based on demographics (e.g., gender) may be considered, as such analyses could have more power to detect group differences.

Finally, the neural substrate underlying ECT performance remains to be established. The latter may be accomplished via functional magnetic resonance imaging to further explore similarities and differences in the networks of the four ECTs, and with magnetoencephalography to explore timing of the various perceptuomotor versus EF components of the tasks. In sum, although the present results are somewhat promising, we propose that future directions should be aimed at providing further evidence about the construct validity of the ECTs to support specific interpretations about task performance.

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Appendix A:

Demographics Questionnaire

ID #: ________

Demographic Information:

Age: _________

DOB: ____________________

Gender: Male Female

Handedness: Right Left

Highest Level of Education or Year in School: ____________________

Primary Language: ____________________

How many people are in your nuclear family (including self): _________

Of these, how many are left-handed: _______

What ethnicity do you associate most strongly with?

African American Caucasian Hispanic Asian and Pacific Islander

Native American Middle Eastern Other:________________________

History:

Any history of psychiatric disorders (i.e., depression, anxiety) in you or your immediate family? Yes No

If YES, what and in whom?

Any history of learning disorders (e.g. dyslexia) in you or your family members? Yes No

If YES, what in whom?

Any history of ADHD in your immediate family? Yes No

If YES, in whom?

Any history of neurological disorders (i.e., traumatic brain injury, epilepsy, dementia) in you or your immediate family? Yes No

If YES, what and in whom?

Any current medications prescribed: Yes No

If yes, what are they, dosage, frequency and how long: ________________________

Vision related problems (w/o glasses or contacts): Yes No

Appendix B:

Informed Consent Document

General Information
Study title: Concurrent validity of the elementary cognitive tasks

Person in Charge of Study (Principal Investigator): David C. Osmon, Ph.D., ABPP-CN, Department of Psychology, University of Wisconsin-Milwaukee (UWM).

Study Description: You are being asked to participate in a research study. Your participation is completely voluntary. You do not have to participate if you do not want to. This study investigates the use of elementary cognitive tasks (ECTs), basic tasks which require only a small number of mental processes with easily specified correct outcomes, compared to already established executive functioning (EF) tests, which measure working memory, reasoning, mental flexibility, and problem solving, and planning. This study should take approximately 4 hours. In total, we expect to recruit 120 UWM undergraduate psychology students. All of the study activities will be completed in the rooms located within Garland Hall Suite 338.

Study Procedures: If you agree to participate, you will be given a demographic questionnaire, four ECTs and the following EF tests: Delis-Kaplan Executive Function System (D-KEFS), two modules of the Neuropsychological Assessment Battery (NAB; Attention Module and Executive Function Module), the Stroop, and the Shipley-2 Abstraction and Shipley-2 Vocabulary. No audio/video/photographic recordings will be taken during the study. All study activities will be completed in the rooms located within Garland Hall Suite 338.

Risks and Minimizing: The risk associated with the study is minimal and is not anticipated to be greater than the risk associated with performance of routine psychological testing.

Benefits: The only benefit to participating in this study, outside of furthering the science of psychology, is that you may receive extra credit in your psychology course via SONA. Whether you will receive extra credit is determined by your instructor and cannot be guaranteed by the Principal Investigator (PI) of the study.

Study Costs: You will not be responsible for any of the costs from taking part in this research study.

Confidentiality: All information collected about you during the course of this study will be kept confidential to the extent permitted by law. We may decide to present what we find to others, or publish our results in scientific journals or at scientific conferences. Information that identifies you personally will not be released without your written permission. Only the Principle Investigator and a small number of research assistants under his supervision will have access to your information. However, the Institutional Review Board at UW-Milwaukee or appropriate federal agencies, like the Office for Human Research Protections, may review your records. Since the data will be collected in a single visit, you will receive a random ID that will not be linked to you name at all. There will be no separate sheet containing both names and IDs either.

That way data will be de-identified throughout the entire study. Thus, your scores will not be linked to your name either. Participants will be completing the measures and data analysis will be done per test, so the data will be reported in terms of group performance on each test. All informed consents and data will be stored in separate binders in a locked area in the Adult Neuropsychology Research Lab located in Garland Hall Suite 338. The computer data will be kept on a password-protected computer in the Adult Neuropsychology Research Lab, where it can only be accessed by the Principle Investigator and research assistants. All data will be kept for a maximum of 3 years, and then deleted or shredded. To ensure that you receive extra credit for your participation, your name will be recorded on SONA, which is in no way associated with the study data.

Alternatives: If you do not wish to participate in this study but still wish to earn extra credit, there are other extra credit opportunities available in this lab and other psychology labs at UWM. Contact information for these other opportunities will be provided upon request.

Voluntary Participation and Withdrawal: Your participation in this study is entirely voluntary. You may choose not to take part in this study. If you decide to take part, you can change your mind later and withdraw from the study. You are free to not answer any questions and may withdraw at any time. Your decision will not change any present or future relationships with the University of Wisconsin-Milwaukee. Your refusal to take part in this study or decision to withdraw from the study will not affect your grade or class standing in any course. If you decide to withdraw from the study early, we will not use the information collected up to that point in our data analysis. If you become upset and/or do not want to answer a question during the screening interview or the experiment, you can stop at any time, your data will not be used, and you will still receive extra credit for your time.

Questions?
Who do I contact for questions about this study?
For more information about the study or the study procedures or treatments, or to withdraw from the study, contact:
David C. Osmon, Ph.D., ABPP-CN
Department of Psychology
P.O. Box 413
Milwaukee, WI 53201
(414) 229-6751

Who do I contact for questions about my rights or complaints towards my treatment as a research subject? The Institutional Review Board may ask your name, but all complaints are kept in confidence.
Institutional Review Board
Human Research Protection Program
Department of University Safety and Assurances
University of Wisconsin – Milwaukee
P.O. Box 413
Milwaukee, WI 53201
(414) 229-3173

Research Subject's Consent to Participate in Research:
To voluntarily agree to take part in this study, you must sign on the line below. If you choose to take part in this study, you may withdraw at any time. You are not giving up any of your legal rights by signing this form. Your signature below indicates that you have read or had read to you this entire consent form, including the risks and benefits, and have had all of your questions answered, and that you are 18 years of age or older.

ID #: __________

____
Printed Name of Subject/ Legally Authorized Representative

____ _____________________
Signature of Subject/Legally Authorized Representative Date

Principal Investigator or Designee or RA
I have given this research subject information on the study that is accurate and sufficient for the subject to fully understand the nature, risks and benefits of the study.

____ _____________________
Printed Name of Person Obtaining Consent Study Role

____ _____________________
Signature of Person Obtaining Consent Date

CURRICULUM VITAE

OCTAVIO A. SANTOS

WORK CONTACT

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San Antonio, TX 78238
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Email: osantossolano@gmail.com

EDUCATION

2016-Present Psychology Internship–Neuropsychology Track, APA-Accredited Program
South Texas Veterans Health Care System; San Antonio, TX

2011-Present PhD, Clinical Psychology, APA-Accredited Program
Member of the Academy of Psychological Clinical Science
University of Wisconsin-Milwaukee; Milwaukee, WI
Academic Advisor: David C. Osmon, PhD, ABPP-CN
Dissertation Topic: Elementary Cognitive Tasks of Executive Functioning: A Concurrent Validity Study (Defense: 7/2016)

2011-2014 MS, Psychology
University of Wisconsin-Milwaukee; Milwaukee, WI
Academic Advisor: David C. Osmon, PhD, ABPP-CN
Master's Thesis: Using Information Theory and Elementary Cognitive Tasks to Formally Define Executive Functions (Defense: 2/2014)

2000-2005 BS, Psychology (summa cum laude)
Pontificia Universidad Javeriana; Bogotá, Colombia
Academic Advisor: Juan D. Gómez, PhD
Honor's Thesis: A Pilot Study of the Effectiveness of a Computerized Training Program upon Performance in Tests Assessing Sustained Attention and Inhibitory Control in Children with ADHD (Defense: 10/2005)

LANGUAGE PROFICIENCIES

Spanish and English

HONORS & AWARDS

Fellowships and Scholarships

2015	Summer Research Fellowship, UWM Department of Psychology ($3,178)
2014	Diversity Scholarship, American Academy of Clinical Neuropsychology ($500)
2012-2015	UWM Advanced Opportunity Program Fellowship ($15,000 yearly)
2012	Diversity Scholarship, American Academy of Clinical Neuropsychology ($500)

Travel Awards

2016	UWM Health Psychology Graduate Student Club ($2,000)
2015	UWM Association of Graduate Students in Neuropsychology ($2,000)
2015	UWM Health Psychology Graduate Student Club ($1,880)
2015	UWM Association of Graduate Students in Psychology ($2,000)
2015	UWM Advanced Opportunity Program ($1,000)
2015	American Psychological Association ($300)
2014	UWM Graduate School ($1,000)
2014	APA Division 45 ($1,000)
2013	UWM Graduate School ($1,200)
2013	UWM Association of Graduate Students in Psychology ($1,800)
2013	APA/APAGS Ambassador ($500)
2012	UWM Association of Graduate Students in Psychology ($1,500)
2012	APA/APAGS Ambassador ($500)
2012	APA/APAGS-CARED Meeting ($300)
2012	State Leadership Conference ($300)

Certificates of Recognition and Appreciation

2016	Certificate of Recognition, APA Division 40/ANST
2014	Certificate of Recognition, UWM Roberto Hernandez Center
2014	Certificate of Recognition, UWM Advanced Opportunity Program Fellowship
2014	Certificate of Appreciation, APA/APAGS Convention Ambassador Program
2014	Student Highlight, APA Division 52
2013	Certificate of Appreciation, APA/APAGS Convention Ambassador Program
2013	Certificate of Recognition, APA/APAGS-CARED
2012	Student Highlight, APA Division 40/ANST

Other Honors and Awards

2015-2016	Nomination, APA Distinguished Graduate Student in Professional Psychology
2012	Nomination, APA Division 40 Pearson Minority Investigator Award
2012	WIL Sponsorship Program, National Academy of Neuropsychology
2012	Golden Key Honor Society Top Academic Achiever ($150)
2011	Alzheimer’s Disease Core Center Achievement Award
2006	Xavierian Academic Merit Prize, Pontificia Universidad Javeriana
2003	National Award in Basic Medical Sciences, Colombian Association of Biological Sciences

SUPERVISED CLINICAL EXPERIENCE

Neuropsychology Rotations

07/2016-Present — South Texas Veterans Health Care System; San Antonio, TX

Supervisor(s): Karin McCoy, PhD, ABPP-CN, Jason Soble, PhD, ABPP-CN, & Janice Marceaux, PhD.

Population(s): Epilepsy, neoplasm, polytrauma, psychiatric, anoxic, medication-induced, cerebrovascular, neurodegenerative, movement, ADHD and learning disorders, and normal aging.

Duties: Conduct comprehensive outpatient adult neuropsychological evaluations in English/Spanish and report writing, including decisional capacity. Perform semi-structured clinical interviews and feedback sessions for patients and their caregivers. Review medical records for case presentations prior to evaluations. Present and participate in neuropsychology (fact-finding) case conference, grand rounds, journal club, and research meetings. Attend weekly neurology grand rounds. Conduct research on performance on naming tests in bilinguals. Co-lead groups for coping with cognitive problems.

08/2015-05/2016 — UWM Learning Disability Specialty Clinic; Milwaukee, WI

Supervisor(s): David C. Osmon, PhD, ABPP-CN.

Population(s): TBI, ADHD, developmental and learning disorders.

Duties: Conducted comprehensive outpatient adult neuropsychological evaluations in English/Spanish and report writing. Supervised graduate students on administration and scoring of neuropsychological measures.

06/2015-05/2015 — Clement J. Zablocki VA Medical Center; Milwaukee, WI

Supervisor(s): Thomas Hammeke PhD, ABPP-CN, Eric Larson, PhD, ABPP-CN, & Kathleen Patterson, PhD, ABPP-CN.

Population(s): Epilepsy, neoplasm, polytrauma, ADHD, psychiatric, cerebrovascular, neurodegenerative, movement and learning disorders.

Duties: Conducted brief inpatient and comprehensive outpatient adult neuropsychological evaluations and report writing, including TBI diagnosis in OEF/OIF veterans, C&Ps and decisional capacity. Performed semi-structured clinical interviews and feedback sessions for patients and their caregivers. Reviewed medical records to identify older adults at risk for MCI/dementia requiring neuropsychological evaluation. Presented in weekly

Geropsychiatry Clinic team and neuropsychology (fact-finding) case conference meetings. Attend weekly psychiatry grand rounds.

06/2014-05/2015 Froedtert & the Medical College of Wisconsin; Milwaukee, WI

Supervisor(s): Sara Swanson, PhD, ABPP-CN, Michael McCrea, PhD, ABPP-CN, Julie Bobholtz, PhD, ABPP-CN, David Sabsevitz, PhD, ABPP-CN, & Laura Umfleet, PsyD.

Population(s): Epilepsy, neoplasm, TBI, neurodegenerative, infectious, cerebrovascular, demyelinating, movement, developmental and learning disorders.

Duties: Conducted brief inpatient and comprehensive outpatient adult neuropsychological evaluations in English/Spanish and report writing, including IMEs, decisional capacity, and pre-/post-surgical DBS and MTLE. Assisted with Wada testing for epilepsy pre-surgical evaluations. Performed semi-structured clinical interviews and feedback sessions for patients and caregivers. Presented in weekly journal club meetings. Attended weekly seminars, neurology grand rounds, and neuropsychology (fact-finding) case conference meetings.

12/2012-01/2013 Hospital de la Santa Creu I Sant Pau; Barcelona, Spain

Supervisor(s): Carmen G. Sánchez, PhD.

Population(s): Neurodegenerative and cerebrovascular.

Duties: Observed brief inpatient and comprehensive outpatient adult neuropsychological evaluations, report writing, and feedback sessions. Participated in medical records and neuroimaging reviews. Consulted on the selection of appropriate neuropsychological measures to best address the referral question(s). Attended weekly neuropsychology case conference meetings.

06/2008-05/2011 Barrow Neurological Institute; Phoenix, AZ

Supervisor(s): Leslie Baxter, PhD, ABPP-CN.

Population(s): Neurodegenerative, epilepsy and neoplasm.

Duties: Conducted comprehensive outpatient adult neuropsychological evaluations in English/Spanish and report writing. Assisted with fMRI pre-surgical mapping evaluations in English/Spanish. Attended weekly functional neuroimaging seminars, neuropsychology (fact-finding) case conference, neurology grand rounds, and biweekly Arizona Alzheimer's Disease Core Center meetings.

01/2005-06/2005 Centro de Investigaciones Neurológicas y Psicológicas; Bogotá, Colombia
Supervisor(s): Patricia Pitta, MA.
Population(s): Neurodegenerative, epilepsy, neoplasm, cerebrovascular, TBI, learning disorders and ADHD.
Duties: Conducted comprehensive outpatient adult and pediatric neuropsychological evaluations and report writing. Performed cognitive rehabilitation with patients. Provided feedback to patients and caregivers. Attended and presented in weekly neuropsychology case conference meetings.

07/2004-12/2004 Hospital Universitario San Ignacio; Bogotá, Colombia
Supervisor(s): Juan D. Gómez, PhD.
Population(s): Epilepsy, neoplasm, cerebrovascular and TBI.
Duties: Conducted brief and comprehensive outpatient adult neuropsychological evaluations and report writing. Attended and presented in weekly neuropsychology case conference meetings.

Clinical Psychology Rotations

06/2015-12/2015 The Bridge Health Clinics and Research Centers; Milwaukee, WI
Supervisor(s): Todd C. Campbell, PhD, CSAC, ICS.
Population(s): Substance use, personality, and anxiety/mood disorders, HIV/AIDS, ADHD and parole/probation.
Duties: Completed substance abuse training for SAC-IT certification. Conducted comprehensive and semi-structured outpatient adult psychological evaluations in Spanish and report writing. Independently led and co-lead group psychotherapy and psychoeducation in Spanish, including CBT and MI. Completed intake reports, develop treatment plans, and compose progress and termination notes.

03/2014-05/2014 UWM Norris Health Center; Milwaukee, WI
Supervisor(s): Barbara Moser, MD, Aamir Siddiqi, MD, Christopher Martell, PhD, ABPP-CP, & Paul Dupont, PhD.
Population(s): Substance use, anxiety/mood and eating disorders.
Duties: Conducted initial triage assessments and referrals for patients for Tier-2 depression and suicidal ideation evaluations. Performed brief individual psychotherapy for depression self-management. Collected clinical data for use in a center-wide pilot screening project. Participated in the Chancellor's Advisory Committee on Mental Health.

09/2013-08/2015 — UWM Psychology Clinic Psychotherapy Team; Milwaukee, WI
NIMH Program of Excellence Training in Scientifically Validated Interventions
Supervisor(s): Shawn Cahill, PhD & Robyn Ridley, PhD.
Population(s): Personality, anxiety/mood and adjustment disorders.
Duties: Performed short- and long-term individual evidence-based psychotherapy and psychoeducation, including CBT, PE, and ERP. Completed integrated assessment reports, developed treatment plans, and composed progress and termination notes. Presented in weekly case conference meetings.

09/2012-05/2013 — UWM Traumatic Stress & Anxiety Disorders Clinic; Milwaukee, WI
Supervisor(s): Shawn Cahill, PhD.
Population(s): PTSD and other anxiety disorders.
Duties: Conducted comprehensive assessments using semi-structured interviews to inform diagnostic formulation and completed integrated reports. Presented in weekly case conference meetings.

09/2011-05/2013 — UWM Psychology Clinic; Milwaukee, WI
Supervisor(s): Bonita Klein-Tasman, PhD & Han Joo Lee, PhD.
Population(s): Personality, anxiety/mood, developmental and learning disorders.
Duties: Conducted semi-structured interviews and comprehensive adult and pediatric psychological evaluations, and completed integrated reports. Provided evaluation feedback to patients and their caregivers. Presented in weekly case conference meetings.

07/2003-06/2004 — Alternativas de Intervención Psicológicas; Bogotá, Colombia
Supervisor(s): Carolina Barbosa, MA.
Population(s): Anxiety disorders, ADHD, conduct, developmental and learning disorders.
Duties: Conducted semi-structured interviews and comprehensive adult and child/adolescent psychological evaluations, and completed integrated reports. Performed short- and long-term individual psychotherapy using CBT. Designed and led group-based social skills interventions for elementary school children. Developed treatment plans and composed progress notes and termination summaries. Presented in weekly case conference meetings.

Specialized Training

07/2015 — Neuroanatomical Dissection: Human Brain and Spinal Cord 3-day Course
Marquette University, College of Health Sciences; Milwaukee, WI

06/2015-07/2015 Substance Abuse Counselor-In-Training Certification (100 hours)
Wisconsin Department of Safety and Professional Services; Madison, WI

06/2014 NIH Toolbox Training 2.5-day Workshop
Northwestern University; Chicago, IL

05/2012 Federal Advocacy Training 1-day Workshop and Congressional Visits
American Psychological Association; Washington, DC

SUPERVISED RESEARCH EXPERIENCE

09/2011-05/2016 UWM Adult Neuropsychology Research Lab; Milwaukee, WI
Supervisor(s): David C. Osmon, PhD, ABPP-CN.
Duties: Assist with development and implementation of research projects and computerized cognitive tasks. Conduct statistical analyses and write-ups for publication and presentation. Supervise undergraduate research assistants.

06/2008-05/2011 Human Brain Imaging Lab, Barrow Neurological Institute; Phoenix, AZ
Supervisor(s): Leslie Baxter, PhD, ABPP-CN.
Duties: Assisted with fMRI protocol implementation, quantitative data collection and analyses, literature searches, and poster preparation. Conducted study recruitment within the elderly Hispanic community. Performed initial study eligibility screenings.

02/2008-05/2008 Columbia University Medical Center; New York City, NY
Supervisor(s): Bernadette Boden-Albala, MPH, DrPH.
Duties: Conducted standardized follow-up interviews and cognitive screening in English/Spanish. Assisted with qualitative and quantitative data collection.

01/2006-10/2006 Universidad Industrial de Santander; Bucaramanga, Colombia
Supervisor(s): Carlos A. Conde, MD, PhD.
Duties: Assisted with participant recruitment, screening, scheduling, data entry, literature searches, and poster preparation. Conducted electromyographic and spirometric data collection.

01/2003-12/2003 Pontificia Universidad Javeriana; Bogotá, Colombia
Supervisor(s): Raúl Oyuela, MPhil.
Duties: Assisted with project design, literature review, data collection and analysis, manuscript preparation, and research presentation.

Funded Grants

01/2014-01/2015	Project Title:	Promoting brief, evidence-based assessment and intervention in interdisciplinary healthcare settings: An online educational toolkit and convention program for trainees.
	Source:	American Psychological Association.
	Type:	CODAPAR program development grant.
	Role:	Co-Developer.
	Amount:	$1,550

01/2014-01/2015	Project Title:	Using information theory and elementary cognitive tasks to formally define executive functions.
	Source:	Sigma Xi Honor Society.
	Type:	Grant-in-Aid of Research.
	Role:	Principal Investigator.
	Amount:	$600

Grant Review Experience

2014-Present	Mentoring Committee, Hispanic Neuropsychological Society
2014	Division 52 Student Committee, American Psychological Association
2013	Clinical Research Grants Committee, National Academy of Neuropsychology
2011-2013	Committee for the Advancement of Racial/Ethnic Diversity, APA/APAGS

PUBLICATIONS

Refereed Publications

1. Calderón, A., Cadavid-Ruiz., N., & Santos., O.A. (in press). Aproximación Práctica a la Rehabilitación de la Atención. *Revista Neuropsicología, Neuropsiquiatría y Neurociencias.*
2. Lequerica, A.H., Vega, M., Belen, K., Salinas, C.M., Marquez de la Plata, C., Pappadis, M.R., Santos, O.A., & Arango Lasprilla, J.C. (in press). Estado actual de la rehabilitación cognitiva en personas de habla hispana en los Estados Unidos. *Revista Neuropsicología, Neuropsiquiatría y Neurociencias.*
3. Whiteside, D., Guidotti-Breting, L., Butts, A., Hahn-Ketter, A., Osborn, K., Towns, S., Barisa, M., Santos, O.A., Smith, D. (2016). 2015 American Academy of Clinical Neuropsychology (AACN) student affairs committee survey of neuropsychology trainees. *The Clinical Neuropsychologist, 30(5), 664-694.*
4. Santos, O.A., Kazakov, D., Reamer, M.K., Park, S.E., & Osmon, D.C. (2014). Effort in college undergraduates is sufficient on the word memory test. *Archives of Clinical Neuropsychology*, *29*(7): 609-613.

5. Oyuela, R., Lareo, L., Munoz, L., Morales, L., Echeverry, S., Uribe, A., Santos, O.A., & Acuna, A. (2004). Efecto en el aprendizaje y la memoria espacial de un péptido sintético en ratas: Estudio preliminar. *Psicología desde el caribe, 13,* 1-14.

Currently Under Review

1. Hughes, A.J., Block, C.K., Hooker, S.A., Santos, O.A., & Eichstaedt, K.E. Understanding and addressing the needs and concerns of interdisciplinary health service psychology trainees: Online assessment and development of a web-based education and training resource.
2. Dassel, K.B., Santos, O.A., Ewen, H.H., & Ogle, K.K. Are health, mood, and stress predictors of subjective memory complaints? CCRC resident experiences.

Non-Refereed Publications

1. Santos, O.A. & Swanson, S.J. (2015). Functional magnetic resonance imaging in bilingual individuals. In American Academy of Clinical Neuropsychology Facebook Page: https://www.facebook.com/AmericanAcademyofClinicalNeuropsychology.
2. Love, C.E., Santos, O.A., & Salinas, C.M. (2014). Diversity and cultural considerations in neuropsychology. In Association of Neuropsychology Student in Training Blog Series: http://www.div40-anst.com/anst-blog-series/chapter-rep-cornerdiversity-and-cultural-considerations-in-neuropsychology.
3. Santos, O.A. (2014). Building Better Brain Health. In American Academy of Clinical Neuropsychology Facebook Page: https://www.facebook.com/AmericanAcademyofClinicalNeuropsychology.

Journal Review Experience

2016-Present	Ad hoc reviewer with Dr. Jason Soble, *Archives of Clinical Neuropsychology*
2011-Present	Ad hoc reviewer with Dr. David C. Osmon, *The Clinical Neuropsychologist*
2009-Present	Ad hoc reviewer with Dr. Kara B. Dassel, *The Gerontologist*

CONFERENCE PRESENTATIONS

Symposia and Workshops

1. Postal, K., Sim, A., Paltzer, J., & Santos, O.A. (2016). AACN's Relevance 2050 Initiative: What it is and why our profession is at risk. Presented at the 14th Annual American Academy of Clinical Neuropsychology Conference, New York City, NY.
2. Love, C.E. & Santos, O.A. (2015). Culturally and linguistically diverse training: Students' perspective. Presented at the 1st Annual Conference of the Hispanic Neuropsychological Society, Austin, TX.
3. Belen, K.E., Judd, T., Thomsom, J.K., Hoese, V.M., & Santos, O.A. (2015). Multilingual and multicultural assessment: An interactive workshop. Presented at the 20th Annual Conference of the National Association of Psychometrists, Austin, TX.

4. Salinas, C.M., Santos, O.A., Berrios-Siervo, G., & Vega, C. (2015). Hispanic Neuropsychological Society mentorship and networking hour sponsored by the International Neuropsychological Society. Presented at the 43rd Annual Meeting of the International Neuropsychological Society, Denver, CO.
5. Salinas, C.M., Rivera-Mindt, M., Vega, C.V., Bender, H.A., Llorente, A., Santos, O.A., & Puente, A. (2014). Cultural neuropsychology roundtable: Training issues and methods for gaining competence in working with diverse individuals. Presented at the 34th Annual Conference of the National Academy of Neuropsychology, Fajardo, Puerto Rico.
6. Hughes, A.J., Boake, C., Turner, A., Jewell, D.M., Hooker, S.A., Block, C.K., Eichstaedt, K.E., & Santos, O.A. (2014). Professional development for students in rehabilitation and health psychology and neuropsychology. Presented at the 122nd Annual Convention of the American Psychological Association, Washington, DC.
7. Salinas, C., Vega, C., & Santos, O.A. (2014). Hispanic Neuropsychological Society mentorship and networking hour sponsored by the American Academy of Clinical Neuropsychology. Presented at the 12th Annual American Academy of Clinical Neuropsychology Conference, New York City, NY.
8. Suzuki, H., Hasan, N.T., Ferdinand, L.A., Lee, J., Hu, G., Santos, O.A., & Wang, W. (2014). How to be an international leader: International ECP perspectives for aspiring leaders. Presented at the 122nd Annual Convention of the American Psychological Association, Washington, DC.
9. Santos, O.A. & Lamas, J. (2013). Advice for emerging professionals, peer mentoring for graduate students. Presented at the 121st Annual Convention of the American Psychological Association, Honolulu, HI.
10. Santos, O.A. (2012). Using information theory and elementary cognitive tasks to define executive functions. Presented at the 14th UWM Psychology Graduate Student Research Symposium, Milwaukee, WI.
11. Madore, M. & Santos, O.A. (2012). Advice for emerging professionals, peer mentoring for graduate students. Presented at the 120th Annual Convention of the American Psychological Association, Orlando, FL.
12. Santos, O.A. (2006). The importance of the neuropsychological assessment in the rehabilitation of head trauma. Presented at the 3rd Eastern Colombian Conference of Occupational Medicine and Occupational Health, Bucaramanga, Colombia.
13. Santos, O.A. (2006). Neuropsychological approach to learning disabilities. Presented at the 1st Neurodevelopment Conference, Bucaramanga, Colombia.

Poster Presentations

1. Santos, O.A. & Soble, J. (2017). Predicting performance on a functional executive measure via a brief cognitive screening test. Abstract submitted for poster presentation at the 45th Annual Meeting of the International Neuropsychological Society, New Orleans, LA.
2. Hahn-Ketter, A., Whiteside, D., Guidotti-Breting, L., Butts, A., Towns, S., & Santos, O.A. (2017). Future directions of neuropsychology from a training perspective: Factors affecting training satisfaction from the 2015 AACN Student Affairs Committee survey

of neuropsychology trainees. Abstract submitted for poster presentation at the 45th Annual Meeting of the International Neuropsychological Society, New Orleans, LA.

3. Santos, O.A., Mirkovic, T., Finman, V.K., Neumann, K.L., Peters, E.R., & Osmon, D.C. (2016). Elementary cognitive tasks of executive functioning: A concurrent validity study. Abstract accepted for poster presentation at the 36th Annual Conference of the National Academy of Neuropsychology, Seattle, WA.
4. Flores-Medina, Y., Santos, O.A., Morth, A.C., Storch, D.A., deGail, N.M., Morrison, T., Hummer, B., & Osmon, D.C. (2016). Adderall's Recreational Users: A Web-Based Survey Of College Students. Presented at the 124th Annual Convention of the American Psychological Association, Denver, Colorado.
5. Whiteside, D., Guidotti-Breting, L., Butts, A., Hahn-Ketter, A., Osborn, K., Towns, S., Barisa, M., Santos, O.A., Smith, D. (2016). 2015 AACN Student Affairs Committee survey of neuropsychology trainees. Presented at the 14th Annual American Academy of Clinical Neuropsychology Conference, Chicago, IL.
6. Santos, O.A., Flores-Medina, Y., Block, C., Rivera, D., & Arango-Lasprilla, J.C. (2016). Neuropsychology teaching-related activities in the U.S.: Results from a professional survey. Presented at the 1st Iberoamerican Congress of Neuropsychology, Bilbao, Spain.
7. Santos, O.A., Block, C., Rivera, D., & Arango-Lasprilla, J.C. (2015). Neuropsychology research-related activities in the U.S. and Canada: Results from a professional survey. Presented at the 35th Annual Conference of the National Academy of Neuropsychology, Austin, TX.
8. Santos, O.A., Morth, A.C., Hummer, B., Storch, D.A., Khokhar, H., deGail, N.M., & Osmon, D.C. (2015). Implicit and explicit personality relationships using NEO PI-R -based IATs and the MMPI-2. Presented at the 123rd Annual Convention of the American Psychological Association, Toronto, Canada.
9. Bergeron, C.D., Santos, O.A., Storch, D.A., Hummer, B., & Osmon, D.C. (2015). Substance use among psychology undergraduates. Presented at the 123rd Annual Convention of the American Psychological Association, Toronto, Canada.
10. Santos, O.A., Sunderaraman, P., Schwarz, L., Mahmood, Z., Block, C., & Thames, A.D. (2015). Are we there yet? Preparation and doctoral-level training in cross-cultural neuropsychology. Presented at the 13th Annual American Academy of Clinical Neuropsychology Conference, San Francisco, CA.
11. Santos, O.A., Finman, V.K., Peters, E.R., Neumann, K.L., Mirkovic, T., & Osmon, D.C. (2015). Concurrent validity of elementary cognitive tasks to measure executive functions: A preliminary study. Presented at the 13th Annual American Academy of Clinical Neuropsychology Conference, San Francisco, CA.
12. Santos, O.A., Park, S.E., Giese, E.M., Langenkamp, M.M., Harmelink, O.L., Zupek, S.J., Anderson, J.J., & Osmon, D.C. (2015). Comparison of ex-Gaussian analysis of reaction time on non-executive and executive elementary cognitive tasks in ADHD and control subjects versus schizotypal and control subjects. Presented at the 43rd Annual Meeting of the International Neuropsychological Society, Denver, CO.
13. Santos, O.A., Reamer, M.K., Park, S., Kennedy-Hettwer, E.J., Peters, E.R., Morth, A., Hummer, B., Boxtel, A.V., Giese, E.M., Harmelink, O.L., & Osmon, D.C. (2014). Effort in college undergraduates. Presented at the 34th Annual Conference of the National Academy of Neuropsychology, Fajardo, Puerto Rico.

14. Bergeron, C.D., Spencer, S.M., & Santos, O.A. (2014). Predictors of caregivers' desire to institutionalize care recipients with dementia. Presented at the 122nd Annual Convention of the American Psychological Association, Washington, D.C.
15. Santos, O.A., deGail, N.M., Morrison, T., Hummer, B., Storch, D.A., & Osmon, D.C. (2014). Implicit self-esteem, explicit self-concept and personality traits discrepancy. Presented at the 122nd Annual Convention of the American Psychological Association, Washington, D.C.
16. Santos, O.A., deGail, N.M, Storch, D.A., Hummer, B., & Osmon, D.C. (2014). Survey of ADHD and learning disabilities feigning in college students. Presented at the 12th Annual American Academy of Clinical Neuropsychology Conference, New York City, NY.
17. Santos, O.A., Park, S.E., Langenkamp, M.M., Zupek, S.J., Anderson, J.J., & Osmon, D.C. (2014). Ex-Gaussian analysis of reaction time on non-executive and executive elementary cognitive tasks in ADHD and control subjects. Presented at the 2014 meeting of the Midwest Neuropsychology Group, Milwaukee, WI.
18. Santos, O.A., deGail, N.M., Green, B., Kozlowski, A.J., Langenkamp, M.M., Bergeron, C.D., & Osmon, D.C. (2014). Prevalence of ADHD malingering in American college students. Presented at the 2014 Annual Conference of the Canadian Public Health Association, Toronto, Canada.
19. Santos, O.A., deGail, N.M, Storch, D.A., Hummer, B., & Osmon, D.C. (2014). ADHD feigning and drug use in college students. Presented at the 2014 Wisconsin Psychological Association Convention, Madison, WI.
20. Hummer, B., Santos, O.A., deGail, N.M., Storch, D.A., & Osmon, D.C. (2014). Implicit-explicit personality discrepancy and self-structure. Presented at the 2014 Wisconsin Psychological Association Convention, Madison, WI.
21. deGail, N.M., Santos, O.A., Green, B., Kozlowski, A.J., Langenkamp, M.M., & Osmon, D.C. (2014). ADHD feigning questionnaire in college students. Presented at the 42nd Annual Meeting of the International Neuropsychological Society, Seattle, WA.
22. Giese, E.M., Santos, O.A., Miller S.J., Potkonjak, K.N., & Osmon, D.C. (2013). Determining the pattern of responses to stimuli associated with direct response versus internal rule elementary cognitive tasks in college students with and without schizotypal personality features. Presented at the 5th UWM Annual Undergraduate Research Symposium, Milwaukee, WI.
23. Park, S.E., Santos, O.A., Langenkamp, M.M., Anderson, J.J., Zupek, S.J., & Osmon, D.C. (2013). Determining the pattern of responses to stimuli associated with direct response versus internal rule elementary cognitive tasks in college students with and without ADHD. Presented at the 5th UWM Annual Undergraduate Research Symposium, Milwaukee, WI.
24. Santos, O.A., Cadavid, N., Giese, E.M., Londono, N., & Osmon, D.C. (2013). Counterbalancing administration of elementary cognitive tasks to define executive functions in Colombian college students. Presented at the 33rd Annual Conference of the National Academy of Neuropsychology, San Diego, CA.
25. deGail, N.M., Santos, O.A., Morrison, T., Gresl, K., Hummer, B., & Osmon, D.C. (2013). Implicit-explicit personality discrepancy and self-structure. Presented at the 5th UWM Annual Undergraduate Research Symposium, Milwaukee, WI.

26. Santos, O.A., Park, S.E., Kennedy, E.J., Giese, E.M., & Osmon, D.C. (2013). Counterbalancing administration of elementary cognitive tasks to define executive functions. Presented at the 121st Annual Convention of the American Psychological Association, Honolulu, HI.
27. Santos, O.A. & Osmon, D.C. (2012). Using information theory and elementary cognitive tasks to define executive functions. Presented at the 120th Annual Convention of the American Psychological Association, Orlando, FL.
28. Santos, O.A. & Osmon, D.C. (2012). Cross-cultural comparison using information theory and elementary cognitive tasks to define executive functions. Presented at the 10th Annual American Academy of Clinical Neuropsychology Conference, Seattle, WA.
29. Green, B., Stockheimer, K., Young, L. Santos, O.A., & Osmon, D.C. (2012). Implicit learning deficits in individuals with dyslexia. Presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, Canada.
30. Santos, O.A., Purcell, M., Liu, S., Caselli, R., & Baxter, L. (2011). Regional decreases in cerebral blood flow associated with increased cerebrovascular risk in cognitively normal older adults. Presented at the 63rd Annual Meeting of the American Academy of Neurology, Honolulu, HI.
31. Castiblanco, M., Mora, A., Pita, P., Santos, O.A., & Uribe, A. (2005). A proposal for an overall neuropsychological rehabilitation program. Presented at the 9th Conference of the Sociedad Latinoamericana de Neuropsicología, Cartagena, Colombia.
32. Oyuela, R., Lareo, L., Munoz, L., Morales, L., Echeverry, S., Uribe, A., Santos, O.A., & Acuna, A. (2004). The effect of a synthetic peptide upon learning and spatial memory in rats: A preliminary study. Presented at the 10th Anniversary of the Human Brain Project, A Decade of Neuroscience Informatics: Looking Ahead, Bethesda, MD.

Other Professional Presentations

1. Santos, O.A. (2016). Cross-cultural neuropsychological assessment: The impact of culture on cognitive test performance. Presented at the Psychology Grand Rounds at South Texas Veterans Health Care, San Antonio, TX.
2. Santos, O.A. (2016). Amphetamines and NDMA: Epidemiology, neuropsychological profile, and neuroimaging findings. Presented at the Neuropsychology Didactics at South Texas Veterans Health Care, San Antonio, TX.
3. Santos, O.A. (2016). Pursuing studies on brain-behavior relationships: A guide for undergraduates interested in clinic neuropsychology with Maria Schultheis, PhD, Eddy Ameen, PhD, and James Garcia, MA. Presented at the 4th Webinar by the Association of Neuropsychology Students in Training, Association for Doctoral Education in Clinical Neuropsychology, and the American Psychological Association of Graduate Students' Committee for the Advancement of Racial and Ethnic Diversity.
4. Santos, O.A. (2016). Board certification via ABPP/ABCN with Linas Bieliauskas, PhD, ABPP-CN/CL, Pamela Dean PhD., ABPP-CN, and Jason Soble, PhD., ABPP-CN. Presented at the 1st Webinar by the American Academy of Clinical Neuropsychology's Relevance 2050 Student Pipeline Subcommittee and the American Board of Clinical Neuropsychology.

5. Santos, O.A. (2016). Mental illness and stigma in the Hispanic population. Presented at a panel discussion sponsored by The Health Collaborative's Young Minds Matter Program. San Antonio, TX.
6. Santos, O.A. (2015). Neuropsychology internship application process with Nina Thomas, PhD, ABPP-CN, Jennifer Gess PhD., ABPP-CN and Melissa Lancaster PhD. Presented at the 3rd Webinar by the Association of Neuropsychology Students in Training, the Society for Clinical Neuropsychology's Education Advisory Committee, and the Association for Internship Training in Clinical Neuropsychology.
7. Santos, O.A., Sunderaraman, P., & Thames, A.D. (2015). Cross-cultural neuropsychology: Training and practice considerations with Tedd Judd, PhD, ABPP-CN and Melissa Castro PsyD. Presented at the 2nd Webinar by the Society for Clinical Neuropsychology's Ethnic Minority Affairs Committee and the Association of Neuropsychology Students in Training.
8. Siwiec, S., Morrison, T., Nagy, G., Santos, O.A., Shollengarger, S., & Wandrey, R. (2014, 2015). Diversity at UWM. Presented at a panel discussion sponsored by UWM the Association of Graduate Students in Psychology.
9. Santos, O.A., Block, C. & Roper, B. (2014). Neuropsychology postdoctoral fellowship application process: Answers to burning questions and recommendations with Jennifer Gess, PhD, ABPP-CN, Steven Bodin PhD, ABPP-CN, Robert Collins PhD, ABPP-CN, and Derin Cobia PhD. Presented at the 1st Webinar by the Association of Neuropsychology Students in Training, the Society for Clinical Neuropsychology's Education Advisory Committee, and the Association of Postdoctoral Programs in Clinical Neuropsychology.
10. Santos, O.A. (2014). The impact of culture on neuropsychological test performance. Presented at the Division of Neuropsychology Journal Club at Froedtert & Medical College of Wisconsin, Milwaukee, WI.
11. Santos, O.A., Cortes, N., Price, C.L., & Abbott, L.M. (2013). I wish I knew then. Presented at a Panel Discussion at the 2013 UWM Graduate Student Orientation Day.
12. Santos, O.A. (2013). A non-typical neuropsychological case presentation of Alzheimer's disease. Presented at the UWM Professional Development in Psychology Seminar.
13. Santos, O.A. (2012). Advice for diverse graduate students with Carmen Vazquez, PhD. Presented at the 2nd Virtual Happy Hour by the American Psychological Association of Graduate Students for the Advancement of Racial and Ethnic Diversity.

TEACHING EXPERIENCE

06/2013-07/2013	Universidad San Buenaventura; Cartagena, Colombia	
	Position:	Instructor.
	Class(es):	Classification of Mental Disorders (DSM-VI-TR, DSM-5).
09/2011-05/2012	University of Wisconsin-Milwaukee; Milwaukee, WI	
	Position:	Graduate Teaching Assistant.
	Class(es):	Social Psychology and Research Methods in Psychology.
07/2006-10/2006	Universidad Manuela Beltrán; Bucaramanga, Colombia	
	Position:	Instructor.
	Class(es):	Neuropsychology; Human Ecology.

07/2001-12/2001	Pontificia Universidad Javeriana; Bogotá, Colombia	
	Position:	Undergraduate Teaching Assistant.
	Class(es):	Seminar on B.F. Skinner.

LEADERSHIP EXPERIENCE

American Academy of Clinical Neuropsychology

2016-Present	Co-Chair, Relevance 2050 Student Pipeline Subcommittee
2015-Present	Member, Relevance 2050
2014-2015	Student Representative, Diversity Committee
2012-Present	Member, Student Affairs Committee

American Psychological Association

2014-2015	Student Team Chair, Presidential Campaign for Antonio Puente, PhD
2013-Present	Liaison Officer, Division 40/ANST
2013-2014	Student Representative, Division 52 Student Committee
2012-2014	Student Representative, Division 40 Ethics Subcommittee
2012-2014	International Resources Coordinator, Division 52 Student Committee
2012-2013	Interest Group Representative, Division 40/ANST
2011-2013	Student Representative, APAGS-CARED

Hispanic Neuropsychological Society

2014-Present	Member, Mentoring Committee
2013-2014	Student Representative, Board of Directors
2012-2013	Student Representative-Elect, Board of Directors

University of Wisconsin-Milwaukee

2013-2014	Student Representative, Clinical Psychology Training Committee
2012-2013	Student Representative, Graduate Student Advisory Council
2011-2012	Vice President, Association of Graduate Students in Psychology

PROFESSIONAL AFFILIATIONS

2014-Present	Midwest Neuropsychology Group
2012-Present	American Academy of Clinical Neuropsychology
2012-Present	National Academy of Neuropsychology
2012-Present	Hispanic Neuropsychological Society
2012-Present	Wisconsin Psychological Association
2012-Present	Psi Chi International Honor Society in Psychology
2011-Present	American Psychological Association (Divisions 20, 31, 40, 45 & 52)
2011-Present	International Neuropsychological Society
2005-Present	Sociedad Latinoamericana de Neuropsicología

PROFESSIONAL REFERENCES

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